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SUPERVISION
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MAJOR TOPIC II - RELATION OF FIRE MANAGEMENT TO OTHER RESOURCE MANAGEMENT WORK.

Subtopic A - Integration and correlation of fire control with other resource management work.

Item 1 - Silvicultural relationships.

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Task Force Chairman - J. Herbert Stone

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SILVICULTURAL PRACTICES AND THEIR RELATIONSHIP TO FIRE CONTROL

Silviculture is defined as the science of growing, reproducing and harvesting stands of timber on a continuous basis. The control of fire is essential if timber crops are to be produced in a controlled and orderly manner.

This nation has gone through several steps in its history before accepting the present position that growing trees are an agriculture crop. These steps were economic in nature. The early pioneers were faced with the necessity of clearing the forests to obtain land for crops and grass in order to survive in the new world. The demands for lumber in the new nation led to early day logging of the "unlimited" supply of timber. There was little thought given to growing a new crop. Fire concerned them only when it threatened their operations or developments. This was the trend in the forested areas from the east coast to the west coast.

During the period of about 1880 to 1900 a few far-sighted men visualized the future growth of our country and could see the need and value of our timbered areas. They could see the necessity of stopping their destruction by wildfire. The importing of a few European-trained foresters and the return of a few men trained in Europe led great emphasis to the need for recognizing trees as a crop. Tremendous emphasis was also given to the entire forestry problem during the early part of the century when millions of acres of public domain lands were placed in Forest Reserves.

The ever increasing demand for forest products in our growing nation in conjunction with the rapid strides, in the last 30 years, to extend adequate fire protection to all our forested areas, is well known by all of us. These

facts have made it economically possible to practice silviculture in nearly all of our forested areas.

SILVICULTURE

Changes in the composition or density of a timber stand influence the many factors associated with it. It influences the soil, water, vegetation, wildlife, microbiology, microclimate and associated factors.

The manipulation of the stand through various silvicultural methods influences these factors in varying degrees. It is within the professional field of the forester to practice the form of silviculture that best fits his needs, economically as well as with the future of the new crop in mind.

The changes in the microclimate and the vegetation, have a direct and marked effect on the fire problem in any silvicultural system.

MICROCLIMATE

Microclimate is greatly influenced by silvicultural systems. Closed stands may be changed to varying degrees of open stand by cuttings. Opening of the crown cover results in higher surface temperatures and greater wind velocities. This, in turn, results in more rapid drying out of surface material and lower fuel moisture during the fire season. It also permits drying out earlier in the spring and late in the fall, thereby extending the fire season.

Studies in closed stands as compared with open stands after logging have shown some striking contrasts. Charles Buck of the California Forest & Range Experiment Station has made measurements during the last few years that give us a definite picture of what can be expected. Conversion of closed stands to open stands has shown the following ratios:

Fuel temperature	1 to 1.5
Fuel moisture	1 to 0.5
Surface wind velocity	1 to 10+

This means that the surface temperature at a given time in a closed stand might be 80 degrees while in an open stand at the same time it would be 1½ times that or 120 degrees. At that same time the fuel moisture in the closed stand might be 8% while it would be 4% in the open stand. Add to these the wind factor of 10 and you have an entire new weather condition to contend with.

Fire danger rating is changed almost immediately after logging. A rating of medium may now be very high or extreme. The probability of fire starting and the rate of spread potential is greatly increased.

The crown canopy is the important factor in establishing these ratios. The silvicultural system can control this crown canopy.

THE VEGETATION (Fuel)

Fuels in the stand are the dead and green materials. The silvicultural practices can determine the kinds, amount and distribution of these fuels.

Logging removes varying amounts of fuel from the area entirely. At the same time it accumulates a great deal of slash and knocks down other material. This puts a lot of the canopy down on the ground where it becomes a real fire hazard. The arrangement and condition of fuels result in an entirely new

problem. The area is almost immediately changed, from perhaps a low hazard area to one of high hazard.

These high-hazard fuels on the ground also usually offer higher resistance to control because of their susceptibility to spot fires and the difficulty of line construction.

MICROCLIMATE AND VEGETATION

The increased fire hazard combined with the increased fire danger ratings gives us a greatly stepped-up fire control problem. Both items are important. However, the change in microclimate perhaps should receive more emphasis in our fire control planning for these areas than it has in the past.

There is little we can do about the microclimate after the silvicultural practice has been accomplished. We must live with the change until vegetation reaches the point that the crown canopy again closes in. The microclimate will gradually become less severe as this occurs.

We have been very much concerned about the slash and other material after logging, and we have done and are doing a lot about them. The early practices of silviculture called for 100% piling and burning - especially in timber sales areas in the west. Piling and burning were fire hazard-reduction measures, which removed the flash fuels but not the heavier materials, and actually removed only a small percentage of the total fuel.

The Second World War, with the resultant labor shortage and increased wages, required us to take a new look at the slash disposal practice on the national forests. Studies in California indicated that slash-fire losses were

as severe in the areas that were 100% piled and burned as they were in adjacent areas of untreated slash. It showed also that the flash fuels were present only for a year or so in the untreated areas and that hazards were much the same in treated and untreated areas after this first year or two. The result was a modified slash-disposal policy - that of piling and burning along roads and strategic areas of use, then lopping the tops over the rest of the area. More emphasis was placed on prevention of fires and initial attack for the first few years after cutting.

Similar trends took place in other regions. This resulted in a modified slash-disposal policy in all the selectively cut silvicultural systems.

FIRE AS A SILVICULTURAL TOOL

Studies in recent years have shown that many of our tree species and timber types owe their existence not only to climate and soil but to fire as well. They are sub-climax in the strict sense of the term. We must recognize, however, that they are climax under the condition in which they developed and existed. Some of these major types are the Douglas-fir of the Northwest, the mixed pine-fir types of the West, the southern pines and the jack pine of the Lake States, to name a few.

This has led to the use of fire as a tool of silviculture as well as a tool for hazard reduction in some areas. It has also led to experiments with the use of fire for both purposes in many other areas.

TIMBER TYPES AND SILVICULTURAL SYSTEMS

A brief review of the conditions in various parts of the country will give us a good understanding of where we stand in this field of silviculture and fire.

REGION 7 - NORTH EAST

The forests here are essentially hardwoods. The silvicultural practice in the hardwoods is tree selection with light cuts per acre. Slash adds little if any to the low fire hazard. Slash disposal is a matter of aesthetics. It is not a silvicultural tool in these types.

The limited areas of mixed softwoods are clear cut in patches. The slash hazard is met by lopping and scattering and increasing the protection from fire. Piling and burning have been given up in these types.

In the pure pine type, lopping and scattering are used - no burning. Limited experimentation in the use of fire for site preparation and the reduction of hardwood invasion are being attempted.

The silvicultural systems have little relation to the protection load. There is no trend toward increased fire hazards due to present practices. The present level of protection (less than 1/10 of 1% annual burn) is such that timber growing is an insurable risk.

REGION 8 - SOUTH

The mountain hardwood types are selectively cut at frequent intervals. Utilization is intense and the only fire protection measure taken is to lop and scatter along main roads. This silviculture treatment is consistent with good fire protection.

The shortleaf pine type is managed to obtain even-aged stands by small watersheds or logging units. The virgin stands are heavily cut, leaving seed trees to produce an even-aged stand. Second growth stands are cut at intervals and in the sequence of fence posts, pulpwood, then sawlogs. Seed trees are left to repeat the cycle. Increased fire hazard in the virgin cuttings is offset by cooperative fire money for a period of three years. The sequence of cuttings for posts and pulp in this second growth area is a fire protection measure. The silvicultural system and fire protection are closely correlated in this type.

The mixed loblolly-shortleaf pine-hardwood type in the Piedmont area is all second growth. It is managed to produce even-aged blocks of pine by operating units. The checkerboard system which results is consistent with good fire control and, therefore, is advantageous to timber production and fire control.

The longleaf - slash pine type stands out above all others in the correlation of fire with silviculture. The stands are worked in sequence for pulp, thinning at 10-year intervals for sawlogs, leaving shelterwood seed trees. The cycle is then repeated. There is no slash disposal except for strips along roads. These stands are fairly open during their growth and the understory is a lush, dense, rank, smothering growth of various shrubs

and grasses. This undergrowth is a very high fire hazard. Fire under strict management is used to (1) reduce this hazard, (2) create a suitable seed bed, (3) control brown spot in longleaf pine and (4) control hardwoods. Silviculture, fire protection, and use of fire as a silvicultural tool, are closely correlated in this type.

REGION 9 - LAKE STATES AND CENTRAL STATES

About 75% of the area cut over annually in this region is in the hardwood types and offers no particular additional problems in fire control. These are: (1) the aspen-paper birch type, which is clear-cut with no slash disposal, (2) oak-hickory and mixed-hardwood types which are being salvage logged for the most part, the cut being light and slash no problem, and (3) northern hardwood-hemlock, which is being selectively logged. Coniferous tops are lopped. The increased fire load is not very significant and no change can be anticipated in the immediate future.

The remaining 25% of the areas cut over each year is in the coniferous types. Here there is an increase in the fire load both from the temporary effect of the slash and debris left on the ground and subsequently from the growth of coniferous reproduction that comes in. This is particularly true in the jack pine type. Much of the jack pine is now being clear cut at maturity or over maturity for pulp wood. The silvicultural system calls for discing the slash areas then planting or in some cases depending on natural seedling. Areas of slash are a high fire hazard until disced. Those areas that cannot be disced offer increased fire load until the slash rots - a period from 7 to 10 years. Some experimenting is being done with prescribed burning as a silvicultural tool.

In this region the pine types offer the only problem and the region seems to be able to handle the increased fire load. As yet fire has not found a definite place as a silvicultural tool.

REGION I - THE NORTHERN ROCKY MTS.

Approximately one-half of the forest area in this region is in young age classes that have, in the last 45 years, been brought through more hazardous conditions than they are likely to experience in a large area at any time in the future. Most of the other half of the area is in old over-mature stands.

The white pine areas are either selectively cut or clear cut. The clear-cut areas are burned after ribes germination. This may be several years later. In the meantime firelines are built for protection. In the selectively cut areas, considerable machine piling and burning are done along roads and spot areas. Hand piling and burning are also used.

Ponderosa pine stands are selectively cut. This type is variable in composition with other species. Since the other species are clear cut, this results in small clear-cut areas in every sale. Machines are used to pile the slash and to create a suitable seed bed. As much of the area as possible is worked in this manner. The piles are later burned. The trend is toward more machine work in all types to reduce the hazard and prepare a seed bed.

The fire problem in the slash areas is highest during the first five years. After that, the hazard is probably lower than in the old virgin stands.

The region cuts around 100,000 acres a year. This means that there will be 500,000 acres within the 5-year high-hazard period. This is a small

problem compared with that in the virgin mature stands. The present slash disposal Coop. and K. V. (seed-bed preparation) appear to be enough to keep up with the increased fire problem.

REGION 4 - INTERMOUNTAIN

This region is primarily concerned with cutting in the ponderosa pine, Douglas fir, spruce fir and lodgepole pine stands.

The ponderosa pine operations account for the greatest area cut and offer the main fire problem. The present silvicultural system is a high-risk tree-selective system. Slash is piled and burned along main roads and ridge tops. The rest is lopped and scattered. The areas are then given additional protection for several years.

A number of the region's fire problems are not answered, but at present fire protection in logged areas seems to be consistent with growing timber.

REGION 2 - THE ROCKY MOUNTAINS

The ponderosa pine type here is managed under a selective silvicultural system. Slash is disposed of by fire or mechanical removal along roads. The cutover areas are blocked out in units of about 80 acres.

The lodgepole pine stands are clear cut in alternate strips. Slash is disposed of by burning along main roads and secondary roads. Nothing is done with the slash in the strips. The uncut strips of mature trees are effective barriers to running fire.

Engleman spruce stands are both selectively and clear cut. They offer more fire problems than lodgepole. Additional hazard reductions are probably needed beyond the present practice.

The fire hazard in these types is increased after logging. However, cutting in this region has progressed at approximately the same rate for many years and the protection forces have been geared to meet the situation.

REGION 3 - THE SOUTHWEST

The region is primarily concerned with the ponderosa-pine type. The silvicultural practice is tree selection. Snags are felled and slash is piled and burned along the roads. The fire hazard is increased at first and then gradually decreases as the light slash disintegrates. Some prescribed burning of slash has been done. More experimentation is planned in the use of fire as a tool in silviculture.

The main fire problem in the region is in the great amounts of reproduction that has come in, or is coming in, as a result of fire protection. This is a bigger problem than the slash areas from a fire control standpoint.

The region seems to be on top of the fire load except for extreme conditions of wind that may occur during the dry period - April through July.

REGION 6

The pine stands - mostly ponderosa pine - in this region are cut under a selective system which removes about 50% or less of the stand. Slash, for hazard reduction, is piled and burned along main roads and strategic ridges. This amounts to about 5 to 15% of the area. Cutting in this type raises the "Rate of Spread Class" one full step. Often the resistance to control is lowered due to roads and skid trails. It is necessary to protect this pine slash for a period of 7 to 10 years until it breaks down to a point when regular protection can handle it.

Clear cutting in staggered blocks of 40 to 80 acres is now the standard practice in the pure and mixed Douglas fir, hemlock and spruce types. The immediate effect of clear cutting is to raise the "rate of spread" index two to three full steps. Old-growth Douglas-fir usually rates as low. After cutting it classifies as high or extreme. Most of these areas are broadcast burned to reduce the fire hazard and as a tool of silviculture. Heavy fuels are not consumed in these burns and the "rate of spread" index remains higher than in the virgin stands. Cooperative funds for additional fire protection do not apply to areas clear cut and burned; therefore, the region is building up an increased fire load without adequate means to handle it. Clear-cut areas that are not burned are given additional protection for a period of several years.

REGION 5

The mixed-conifer types (ponderosa pine, sugar pine, Douglas-fir, white fir and incense cedar) are cut under a poor-risk selective system, taking out about 30% of the stand. Slash, for fire protection, is piled and burned along the main road and strategic ridges. Remaining tops are lopped and all snags are felled. Additional protection is given the areas for about 7 years. After 7 to 10 years, conditions revert to hazard conditions much as they were prior to logging.

The pure pine types on the east side of the Sierra Mountains are open light stands. These are cut on a high risk basis also. Slash and snags are handled as in the mixed-conifer type.

The region is harvesting about 80,000 acres of timber a year. The increased fire load in these areas is being offset for the most part by limited hazard

reduction, increased protection, better roads, and availability of logging crews for fire fighting.

The main fire problem in the region has come about through the dense growth of coniferous reproduction and other vegetation in the timber stands as a result of fire protection over the last 3 or 4 decades. The fire load in the region is still on the increase due to these factors. Fire losses on some ranger districts have been heavy during the last 10 years. Losses have been as high as 2/10 to 4/10 of 1% in the timber-growing stock in some instances.

Fire has not been used as a silvicultural tool to any extent in the region. There has been considerable talk about it and some experimenting has been done on a limited scale.

SUMMARY

The problems may be summarized as follows:

1. Silvicultural systems have a varying but positive effect on the fire control load due to changes in microclimate and the vegetation itself.

2. Silvicultural systems, including stand improvement, have, in general, been developed by timber managers with the objective of producing maximum growth of timber. The need for fire protection was, for the most part, not a direct consideration in their development. For the most part, the fire protection measures, required to assure permanent production, have developed as a result of the silvicultural systems, and not as part of them.

3. The effects of cutting on the fire load are more pronounced in the coniferous types than in the hardwoods under the silvicultural systems now in use.

4. In general, it can be said that in all silvicultural methods of selective cutting in coniferous types, slash is piled and burned along roads and strategic areas as a fire hazard-reduction measure. In nearly all of these systems the snags are felled and all tops are lopped. Clear cutting in coniferous stands is nearly always followed by some piling and burning or by broadcast burning as a hazard-reduction measure.

5. All regions except 5 and 6 have indicated they are keeping up with the fire load that results from the silvicultural systems now being practiced. Region 6 reports they are unable to entirely keep up on clear-cut areas that are broadcast burned because cooperative funds are not then available for additional fire protection. Region 5 studies show they are not now entirely on top of the fire job in the rapidly expanding cutover areas in the Sierras.

6. The increasing fire problems are in the large areas of more or less inaccessible mature and over-mature stands in their heavy growth of young trees and shrubs which have resulted from fire protection itself. These offer a much bigger fire control problem at the present time than do the cutover areas. This is the case now, and it is calculated that it will remain the biggest problem in the immediate future.

7. It is the general opinion that subsequent growth and development of our cutover areas will offer a lesser fire problem than do the virgin inaccessible timber stands we now have.

8. Many of the timber types throughout the country are now recognized as owing their existence to uncontrolled fires in the past. Fire as a silvicultural tool is now recognized and used in some types, and experiments in its controlled use are under way in many other types.

9. The facts indicate that timber management and fire management people are working together closely to insure that silviculture can be practiced on a reasonably sound basis in our timber stands throughout the country.

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MAJOR TOPIC II - RELATION OF FIRE MANAGEMENT TO OTHER RESOURCE MANAGEMENT WORK.

Subtopic A - Integration and Correlation of Fire Control with Other Resource Management Work.

Item 2 - Treatment of Fuels

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TREATMENT OF FUELS

Introduction

Removal or reduction of inflammable fuels is universally accepted as a necessary step to protect any property from fire whether it be wild land, factories, or small homes. Before such a job is actually begun, the inflammable materials are usually classified and inventoried, methods of reduction are considered, the risk of ignition is studied, and the probable relation of the inflammable material to the size of fire or loss of other values is weighed. We will first describe the fuels in different national forest regions and roughly classify the hazard of each. We will then describe possible methods of removing or reducing forest fuels and will show the effectiveness and cost of each. The risk that a given area and kind of fuel will be ignited will usually determine whether fuel reduction needs to be further considered, but in the limited time, we will not discuss risk and its bearing on fuel-reduction policies. Weighing of possible loss against hazard will likewise be omitted. The relation of losses to different classes of forest fuel hazard that are ignited is generally known by foresters. Experience has shown that high hazard fuels, on the average, cause large fire losses.

Groups of Fuels and Relative Hazard of Each

Fuels Not Directly Derived From Cutting

Snags.

The importance of snags as a fire hazard depends on the species, height, length of time that they remain standing, and number per acre. Species that weather and rot in such a way as to form large, thin, porous, easily detached plates on the surface produce large embers that will easily tear loose and float a long way in the draft or horizontal wind and will still be burning when they reach the ground. Flying embers easily ignite the tops of such

species and a surface fire quickly spreads from the ground up the snag bole to the top. Species that develop advanced heart rot within a more firm surrounding shell produce many chimney-like snags in which fire develops a strong vertical draft and burns for a long time. Tall snags are a greater hazard than similar short snags because wind-borne embers reach a greater distance from the snag before falling to the ground. Some western species commonly produce snags over 175 feet tall. Species that resist rot in the roots and bole after the cambium dies are a greater problem because the hazard continues longer. Some species commonly stand for 50 years or more after the tree dies. Many snags per acre over large continuous areas cause an extreme problem compared to sparsely scattered snags. For example, where there are 10 or more highly inflammable snags per acre over a large area, a fire will generally spread rapidly from snag to snag and evade control until those in a wide strip along the control line are cut. If, on the other hand, there are only one or two snags per acre, they will not greatly affect the spread or control.

Regions 1, 3, 5, 6, 7, and 8 consider snags as one of their higher hazard fuels. Regions 1 and 6 have great areas in which dense stands of snags killed by large crown fires are a great hazard. In Region 8, tens of thousands of acres of scattered hardwoods snags are annually created by girdling or poisoning defective and non-merchantable trees.

Blowdown

Patches of blowdown in moderately dense coniferous stands are an extreme hazard. The degree and duration of the hazard depend on the species, size of the trees, rate of decay and time until a new shade canopy is formed.

Criss-crossed tops are highly inflammable when the needles are dry and still attached to the branches. After the needles drop, the branches and twigs attached to the fallen trees ignite rapidly during dry, windy weather. The tangle of boles and branches usually gives extreme resistance to control.

Probably each region at one time or another has extensive blowdowns in the coniferous stands of a given part of the region, but some regions have had exceptionally widespread hazard increase from blowdown. The New England blowdown of 1938 is the outstanding example. Region 6, in the winter of 1951-52, suffered widespread blowdown in extreme western Oregon. The patch-cutting or staggered-setting method of harvest cutting used in the Douglas-fir region has created many hundreds of miles of timber edge along which blowdown is frequent.

Forest Floor Litter

Hazard of the forest floor litter, herbaceous cover, and low brush varies greatly by regions and localities within regions. In the hardwood and hardwood-pine types of Region 7, 8 and 9, the forest floor litter of leaves is highly inflammable in the fall and again in the spring especially where not compacted by snow. The greatest forest floor and undergrowth hazard are found in the coastal plains pine areas of Region 8 where low shrubs and rank dead grass draped with needle litter total as much as 25 tons per acre dry weight. In the ponderosa pine belt of the western regions, the litter and undergrowth are, in general, only moderately hazardous. In Region 5, bear clover, a low shrubby plant of the forest floor, causes the hazard to be high in many areas of ponderosa pine. In the ponderosa pine belt throughout the west, some areas have sufficient annual or perennial

grass to carry fire with high to extreme rates of spread during the summer and fall. These grasses usually offer only low resistance to fire control. The oak woodland areas of the foothills of Region 5 and a small part of Region 6 have a similar flashy grass fuel. In the other coniferous types of the west and east not already mentioned, the forest floor hazard is generally low. When the canopy is removed in most forest types, weeds and grasses that are highly inflammable at certain times of the year increase in density. Brush that causes a higher resistance to fire control may likewise increase. In the western half of Region 6, and the northwest corner of Region 5, a dense cover of annual and perennial weeds springs up soon after the crown canopy is removed by logging, fire, blowdown, etc. Within 3 years after the opening, a large quantity of dead, loosely draped, highly inflammable stalks, leaves and fronds accumulate. This hazardous fuel continues until the weeds are shaded out by tall brush or coniferous regeneration. Resistance to control in this cover type ranges from low to extreme according to the quantity of logs, buried rotten wood, snags, roots, brush and regeneration.

Coniferous Regeneration

Dense stands of coniferous regeneration are a high hazard in all regions during prolonged dry weather. Rate of spread and intensity of heat are great in such circumstances on steep slopes or with moderate or stronger wind. Resistance to control is high to extreme.

Brushfields

Brushfields are an extreme hazard in Region 5 and the southern part of Region 6. As used here, this means a cover mainly of tall broadleaf shrubs and small trees. Many such brush fields are almost impenetrable by a man on

foot and the canopy is well above his head. The accumulation of leaf litter and upright dead stems and twigs in dense stands of brush is highly inflammable and produces a great quantity of heat which usually causes crown fires in the green foliage during the dry season. Control line construction is extremely difficult. Dense stands of sagebrush, which occur in many areas within national forest boundaries of Region 4 and its borders, are a high hazard during low relative humidities and moderate or stronger winds. Intense heat is produced and the fire spreads through the crowns. Resistance to control is moderate to high according to the brush density and method used for control-line construction.

Fuels Directly Derived From Cutting

Slash from the usual hardwood cutting does not significantly increase the normal hazard and will not be discussed here. Since coniferous slash is highly inflammable while the needles remain attached, and the twigs and limbs thereafter are moderately inflammable, the hazard largely depends on the cut per acre and rate of decay. The coniferous slash hazard will be described by broad forest types.

Northern Forest Region of Regions 7 and 9

Slash hazard is high following clear cutting in pure coniferous stands in this forest region and may persist 10 or more years. The area cut by this method on national forest is small. Region 9 estimates that less than 40,000 acres per year are cut in the coniferous types, and much of that is by the selection system. On private lands clear-cutting is prevalent and the slash hazard is great. Much of the jack pine on both national forest and private land is clear cut and the slash hazard should be treated. Selection cutting does not significantly increase the hazard.

Southern Forest Region

In the mountain hardwoods the rate of fire spread is not appreciably increased by the pine or hardwood slash, but the resistance to control is increased. In the upper coastal plains and piedmont the hazard from logging slash is high for about two years wherever an area is much more heavily cut than desirable for good management. In the coastal plains, logging debris quickly rots and does not significantly increase the high hazard of the undisturbed rough.

Ponderosa Pine Belt

In the ponderosa pine belt, which covers a large part of each western region, the slash hazard from the prevailing selection system of cutting is considered by all of the regions to be sufficiently high to justify a substantial hazard-reduction investment. Crowns of the mature trees are 60 feet or more in length and moderately dense. The large resinous needles remain on the slash several years, and a small proportion may remain about 6 years. The slash is highly inflammable and the large pitchy limbs produce great heat. Owing to the group-wise distribution of the mature trees, the cut is often patchily distributed and the slash hazard may be great on one acre and small on the next. Concentrations of tops can be reduced by careful felling. Cutting debris usually is greater in stands containing significant proportions of low value associated species such as Douglas-fir, white fir, and lodgepole pine. These grow in dense understory patches which are often carelessly or purposely smashed in felling and yarding. A slash concentration beneath the low crowned associated firs or a group of immature pine trees will carry a surface fire into the crowns, and during dry windy weather such concentrations

are liable to be the fuse setting off a runningcrown fire. Resistance to control is highly variable from spot to spot, but in stands without dense undergrowth the control line usually can be located where the resistance is low. Dense regeneration or brush may cause high resistance.

Western White Pine and Larch-Douglas-Fir Type of Northern Rocky Mountains.

Where a tree selection cutting is made, the amount of slash per acre is small and the increase in hazard is not significant. Where mature stands are clear cut, the slash is continuous and moderately deep. Hazard is great in both rate of fire spread and resistance to control. As a means of blister-rust control, white-pine slash is not burned until several years after it is cut. This waiting period greatly increases the slash protection load.

Lodgepole Pine.

This type is cut in all of the western regions except Region 3. In the average stand, the slash from clear-cutting will cover most of the ground and remain highly inflammable for several years while the needles are attached. Following light cutting by tree selection or clearcutting of light stands, the hazard is not great.

All Types in the Western One-Third of Region 6.

This area extends from the ocean to the summit of the Cascade Range. The timber types now being cut are various mixtures of conifers which include practically no hardwoods. Douglas-fir is the major portion of the volume cut with western hemlock comprising most of the remaider. The Abies, Sitka spruce, and three of the pines make up the balance. Nearly all of the harvest on the national forests is in mature or overmature

stands which are clearcut. These stands are dense, with 100 to 200 trees per acre, averaging 180 feet in height for the dominants and codominants. Gross volume in the trees over 12 inches d.b.h. averages about 60,000 board feet Scribner and many acres have 100,000 board feet. A tremendous volume of highly inflammable slash is created in logging and, in the numerous stands where the defect associated with overmaturity is one-third of the gross volume, many logs 2 to 5 feet in diameter are left in the slash. Slopes of 60 to 100 percent grade are commonly logged, and these steep slopes increase rate of spread and resistance to control. The summer droughts, which are the rule in this region of heavy rainfall, allow the slash to become very dry. Except on the steeper slopes, from which the slash is dragged into the gullies by logging, debris is almost continuous across the face of a logged area. Rate of fire spread is usually classed high or extreme. This depends on the kind of logging machinery used and proportion of tolerant species, which contribute more fine slash from their longer crowns. Resistance to control is usually classed extreme. Large cull logs, piles of rotten wood, rotten wood extending to one or two feet beneath the surface of the ground, tangles of limbs, and hemlock roots at the surface are the principal obstacles in line construction. About 40,000 acres of this kind of slash are being created each year within national forest protection boundaries.

Methods of Treating Fuels

Mechanical Reduction

Chippers

Mechanical grinding of forest fuels to reduce them to a condition so that they may be readily left on the forest floor is a practice that is

not yet wide-spread. Our survey of the regions indicates that it is being used to a limited extent in at least three regions at this time.

The Fitchburg Chipper produced by the Fitchburg Manufacturing Company of Fitchburg, Massachusetts is the one that first came to our attention in 1950 and has been used in our tests. There are several sizes of this machine that appear to have definite use in our problems of fuel disposal.

When considered strictly from the standpoint of hazard reduction there is question of the practicability of the present machine. Limited use mostly during the past year on two or three forests in the ponderosa pine type on the east side indicates that the unit costs of reduction by chipping will exceed that of piling and burning. Preliminary tests show a cost of approximately $40.00 per acre for chipping as compared with $20 to $25 for piling and burning.

Another factor is that the present chipping machine which is mounted on a 2-wheel trailer is only practical to operate along roads or on very gentle topography. Ideas have been advanced to mount these units on sleds or on tractors. The latter further increases the cost of an already expensive operation.

Costs, of course, are but one of the considerations in weighing the use of such a device for reducing fuels. The values to be gained in developing humus and holding moisture in soils that are otherwise barren or near barren may far off-set the investment in chipping costs.

Limited trials are under way at the Starkey Experimental Range which would seek to restore forage on depleted scab lands on exposed ridge tops in the Blue Mountains of Oregon. Here chips have been produced in slash areas and hauled to an experimental plot where plots have been established with varying amounts of chips per acre to which have been added varying amounts of natural and commercial fertilizers.

Preliminary observation shows that it is possible to establish good stands of forage on these areas where only a few weeds existed before.

Noticeable on these plots is the moisture-holding potential of this chip layer.

Some protection men have questioned chipping as a means of hazard reduction since the same volume of fuel remains. The form and arrangement only are altered.

Without conclusive information, I believe the concensus at this time of protection men is that this means of disposal will be acceptable for most places because only the exposed part of the fuel is subject to rapid drying and high inflammability. Further, the rate of decay will probably be very rapid because of the exposure to air and moisture.

Throwing Into Tractor Roads

Few of the regions are employing the practice of throwing slash into tractor roads during the logging operation as a means of hazard reduction.

Several report that this has been done on a limited basis primarily as a benefit to erosion control. Increased costs, inflexibility as to time of accomplishing the disposal job, and the questionable location of tractor trails as fire breaks are some of the reasons advanced as discouraging this as a generally accepted practice for any large amount of our slash disposal job.

It should not be overlooked as an aid in the control of water where the straight cost of fuel reduction becomes a secondary consideration.

Discing Into Soil

A unique means of slash disposal accomplished as a by-product of the discing of areas as a means of seed-bed preparation for aiding natural regeneration is advanced by one region.

This was something entirely new to me and is a practice which I feel may have considerably wider application in stands which have relatively small volumes of fire fuels to be disposed of, and where tractors can be manuvered through the residual land.

Costs of this practice are reported to be about $20 per acre or $1 per cord in average stands. This, of course, is chargeable only in small part to fuel reduction since it is incidental to the primary purpose of the operation.

Natural Reduction

Lop and Scatter

Lopping and scattering has been and is practiced mostly in selectively cut pine stands at least to some degree in every region of the United States.

The theory of this practice is to change the arrangement of the fuel so that it will constitute a lesser hazard and so that it will lie in closer proximity of the ground where it will gather and retain more moisture and decomposition will thus be hastened.

There appears to be a considerable question expressed by several regions as to whether this practice returns values in reduced hazard commensurate with costs invested. Because of this there appears to be a trend away from the practice in favor of piling and burning where prompt reduction of the fuels is desired and a practice of letting other areas lie as they are where exposure to risk is not critical.

Cost estimates in the regions practicing lopping and scattering vary widely with limits of 15¢ to $1 per M.

Let Lie

A growing preference for treating limited areas of high risk exposure by piling and burning, chipping, lopping and dragging back or other means is indicated by the regions. The balance of the slash on these areas is left as is to disintegrate by natural means. Areas treated are frequently limited to 5-20% of the total cut-over area. These treated areas are usually strips along strategic roads, ridges, streams, or other natural features that will form effective fire breaks to aid in controlling a fire within a small area should one start.

Estimates on time required for natural deterioration vary widely and there unquestionably is a very wide variance between different parts of the country. Some regions indicate that the major portion of the hazard is reduced in a very few years. Most regions indicate a period of 7-10 years is needed for the fuels to approach a state of normality.

Indications are that the trend is to let more fuels deteriorate by natural means in selectively cut stands particularly.

An essential feature recognized by all regions is that an additional protection force is needed if these areas are of any size until nature has reduced the hazard. This additional protection effort should include fast transportation to utilize the road systems developed during logging. It should be aided, if possible, by radio communication for fast and flexible dispatch action and the men should be aided by small tankers and power equipment where practicable to increase the effectiveness of the manpower.

Improved Utilization

Many of us hold as an ideal the utilization of forest products so completely that the problem of treatment of fuels vanishes. In some of the regions, particularly in the east, mid-west, and south, it appears that we are rapidly approaching this point in our utilization or in some cases have actually attained it.

In the western regions the problem is still acute. In extreme cases as much as 60% of the original stand of old growth Douglas-fir timber remains on the ground following logging with original volumes of 50 to 150 thousand board feet to the acre. The disposal of the residue becomes an important problem.

Much work has been done but much more needs to be done to solve this problem. It is tied closely with economics, and as the prices of stumpage rise, new products are created, and the demand for forest products increases, thus increasing our utilization in the woods.

All agree that markets are the real problem involved in the reduction of forest fuels through better utilization.

The F.U.S. has done a splendid job in developing new uses for waste materials in our forests. Most notable of recent developments along this line are core material and even facing for plywood manufactured from logs affected by white pocket rot which heretofore have been considered unmerchantable.

Because of the economics involved, our effort in utilization of waste materials has centered largely around mills where additional transportation costs were not involved in converting waste to usable products. An even greater effort is needed in developing markets for usable products now left in our forests as waste. To encourage this we should continue to tighten the utilization requirements in our timber sale agreements as rapidly as economics will permit. To me this offers the greatest hope for a long-time solution to our problems in the reduction of fuels in our forests.

Chemical Control

Little appears to have been done to date in the field of chemical control specifically for hazard reduction.

Several regions report the use of chemicals to kill brush for planting to reduce soil moisture competition to convert brush areas to grasslands, and to open up areas for wildlife, for brush clearing along roadsides, and for other purposes which has had an indirect effect on the reduction of fuels.

No general application of this as a hazard reduction measure is being practiced and there is some evidence to indicate that it is not presently economically feasible to consider this as a means of fuel treatment for hazard reduction.

Fire

Pile and Burn

Piling and burning have general acceptance as a means of hazard reduction. Use now is limited primarily to clearing up the fuels along strips adjacent to roadsides or along strategic ridges or other prominent topographic features which will allow these to better serve as fire breaks.

The three eastern regions report that they have tapered off to a very minimum of piling and burning. This is due primarily to an unfavorable cost-benefit ratio from a fire control standpoint. Damage to resources including soil and vegetation is given by one region as reason for their reduction in use of this method of reducing hazards.

The inter-relationship of close utilization in these regions cannot be overlooked as a factor affecting their attitude toward any necessity for treatment of fuels resulting from logging.

Western regions appear to be following a relatively uniform pattern of piling and burning to cut large areas of selectively cut ponderosa pine lands into blocks as a pre-control measure. This is then followed by adding additional protection for the balance of the area until natural deterioration takes place.

Estimates of the total amount of slash actually disposed of on these areas varies from 5% to 35% on from 5% to 15% of the total cutting area.

Size of blocks varies from 10 to 160 acres with an average of 20 to 40 acres being the general objective.

Current piling and burning costs vary widely depending on the amounts of fuel on the ground, whether done by hand or machine types of labor available, and many other factors.

A cost of $1.25 per M for a 4 M per acre cut or $6 per acre for the total cut-over area appears to be a representative cost for hand piling and burning. This would represent a cost of $40 per acre minimum for the actual areas treated. Amounts for additional protection must be added to this and result in an average cost per M of 10¢ to 15¢ for the total cut or 40¢ to 60¢ per acre for the total sale area.

A considerable amount of the piling is now being done by machine, and this type of piling and burning seems to be on the increase. Because the purpose of our piling and burning is to reduce fuels along strategic breaks as a pre-control measure and not primarily as a fire prevention measure, it becomes important that as many heavy fuels on these strips remaining from logging be disposed of as possible since these are the fuels that will create intense heat and cause spotting or crowning across a control line. Machine piling facilitates the disposal of these heavy materials that could not otherwise be accomplished by hand methods. There are, of course, limitations on the slopes and ground conditions which permit the use of machines in piling. Because of these factors and the desire to move heavy materials, many prefer large machines of the D-7 class. Advantage in use of larger machines must be weighed against greater disturbance of soil and damage to reproduction for any given area. Some consider soil disturbance desirable because of the advantage as a seed bed.

Costs of machine piling vary widely but a representative figure under average conditions might run $18 to $20 per acre.

A recent development in slash piling is the use of a 30-30-30 Kraft laminated reinforced paper covering placed on the pile at the time it is built. This sheds precipitation and keeps the pile dry so it is easily ignited when other fuels are so saturated fire will not spread. This results in lowered cost of firing, more complete consumption of the pile without "chunking-in," a minimum of expense to prevent fires from spreading, and reduced damage to adjacent trees and reproduction.

Piling and burning of 100% of slash on selectively cut areas are no longer practiced except for special purposes other than fire protection, primarily because of cost with relation to benefit but with consideration given to the effects of fire on soil, in destruction of material that may be added as humus to the soil and because of damage to reproduction and timber. It is still widely practiced in the western regions as a medium of breaking up large areas of slash to make control action of extra protection forces more effective.

Concentration Burning

Concentration burning seems to have limited application over wide areas. It is used to reduce the greatest concentrations of fuel on limited areas under very favorable conditions and with minimum costs.

Our experience indicates concentration burning to be risky practice without adequate precaution to prevent the spread of fire from the area planned for burning by fire lines. Reverses in weather with large quantities of fuel adjacent can result in disaster from this type of burning.

Work is being done to develop a wind machine which will create a forced draft on concentrations of fuels in draws or at landings which will permit them to be ignited with oil, goop, or other substance and force burned under conditions which will not permit the spread of fire to adjacent fuels. This is being used considerably in connection with the burning of fuels on rights of way under conditions which will not endanger adjacent values.

Broadcast Burning of Slash

The broadcast burning of slash as a hazard reduction measure is being practiced generally in the west side Douglas-fir type of Western Oregon and Washington and to a lesser degree elsewhere in Idaho and California in white pine, Douglas-fir, and fir-redwood types. It is also being used to a limited degree in the Lake States and perhaps elsewhere.

The use of fire in broadcast burning large clear-cut areas of slash is a very controversial practice. Too little is known as to the effects of this practice on the soil, water, erosion, and plants. A great deal of research effort has gone into this subject but a great deal more is needed.

Broadcast burning is accomplished by doing the utmost in preparation in advance. It involves the lay-out of the timber sale, the cutting practices and the logging practices. Fire lines are then developed around most areas and all snags are felled within the cutting units and for a distance outside the cutting units. Actual burning is done under the most favorable weather possible and generally in the late fall during the drying out period following a heavy rain. Dependent as the practice is on favorable weather conditions, it is a very risky practice and frequently results in heavy costs in firefighting and much damage to surrounding timber.

Broadcast burning properly done will reduce an extreme or high rate of spread fuel to a low rate of spread and from an extreme or high resistance to control to a low or moderate resistance to control. This effect is temporary because of the encroachment of annual and perennial weeds and a further breakdown of the charred fuels which remain. These values may rise to a high rate of spread and moderate to high resistance to control again before the stand is re-established and a closed canopy is developed over the area which may take as much as 20 to 40 years.

It should be noted that broadcast burning of slash is a method generally associated with the conversion of decadent old-growth stands which is the big problem in the timber types mentioned. Once this conversion is made it is likely that the use of fire in broadcast burning for reduction of fuels resulting from cutting will diminish in importance. Utilization will increase in young stands to a point where broadcast burning will be undesirable.

Costs of broadcast burning have increased rapidly as the value of stumpage and fire fighting costs have increased. In the heavy slash of the Douglas-fir region disposal by this method will cost approximately $20 to $30 per acre or 50¢ to 60¢ per M on a cut of 50 M per acre.

Broadcast Burning of Other Fuels

Broadcast burning of blowdown or beetle-killed areas is sometimes practiced in the reduction of fuels in lodgepole pine types. This is accomplished by isolating the area to be burned by fire lines and burning during favorable weather conditions.

Snag areas in the northwest are sometimes treated by felling corridors or snag breaks through large unbroken areas of snags. These snags will run to the bottom of drainages in steep topography and concentrate in great piles. These piles of fuels are sometimes broadcast burned during the winter season to reduce the tremendous amount of fuels.

Cost of snag falling vary widely but will average $1 to $1.50 per snag in the western Oregon Douglas-fir region. There may be 50 snags per acre in some old burns so that costs of disposal may run up to $50 to $75 per acre for the acres actually treated for felling alone. Burning costs are usually small where this is done.

Broadcast burning in certain timber types in the south is practiced extensively. Many thousands of acres are treated annually. Many other factors enter into this practice of broadcast burning including seed-bed preparation, control of brown-spot disease in long-leaf pine and release of competing brush species.

To a lesser degree several other regions indicated the use of fire in broadcast burning for other reasons. Reduction of fuels is inevitably at least a by-product in the use of fire for thinning in "dog-hair" ponderosa pine reproduction, sage brush burning for range improvement in the northwest and intermountain regions and in the brush types of California.

The southwest region is doing considerable in broadcast burning of large areas prior to logging primarily as a hazard reduction measure.

Most regions indicate a need for better information in connection with the use of fire in broadcast burning. Much of such burning now being done is actually experimental.

Summary

Reduction of high hazard fuels is generally accepted as a necessary step to adequately protect forests from fire.

Snags are rated as a high hazard fuel in Regions 1, 3, 5, 6, 7, and 8. Regions 1 and 6 have great areas of dense stands of fire-killed snags and Region 8 has great areas of scattered snags killed by girdling or poisoning defective and nonmerchantable trees.

Blowdown in dense coniferous stands creates an extreme hazard.

Forest litter of the hardwood types in Regions 7, 8, and 9 is highly inflammable in the spring and fall. The greatest hazard from forest floor, grass, and undergrowth fuels is in the coastal plains pine areas of Region 8. Such fuels in the ponderosa pine belt of the west are, for the most part, moderately hazardous, but in some localities rate of spread is high to extreme owing to flashy undergrowth or more than the normal amount of grass. Other coniferous types usually have a low hazard under the crown canopy. After crown removal, weeds and undergrowth cause a high hazard in the western part of Region 6.

Brushfields in Region 5 and the southern part of Region 6 are an extreme hazard.

Dense coniferous sapling stands are a high hazard.

Slash from hardwood cutting and from light-selection cutting in conifers does not significantly increase the hazard. Slash from the prevailing selection cutting in the ponderosa pine belt sufficiently increases the hazard to justify a reduction investment. Clear cutting in dense stands of conifers creates a high to extreme hazard.

Mechanical methods are not now being widely employed in the reduction of forest fuels. Methods now employed to limited extent are use of chippers throwing materials into cat roads and cutting into pieces by discing.

Lopping and scattering of slash in selectively cut stands appears to be less used as a means of disposal than it once was.

A growing tendency to leave more slash in selectively cut stands to deteriorate by natural means is indicated. Additional protection during the period of deterioration is considered essential.

Improved utilization is perhaps the soundest longtime approach to the problems of treatment of fuels in the forest for hazard reduction. Economics will largely govern our progress in the field of utilization, but continuing effort is needed on our part to improve it wherever possible.

Chemical control is not yet developed to the point of wide use in treatment of fuels for hazard reduction.

Piling and burning continue to be a preferred method of treating slash in selectively cut stands of ponderosa pine and other coniferous stands. A tendency to use this means to reduce large areas to smaller blocks and with added protection to wait for natural deterioration seems evident. The use of machines for piling has reduced costs of this method where applicable. Covering of piles with paper has lengthened the burning season and reduced damage from burning.

Concentration burning is used to a limited degree. It poses threats to adjacent values which must be carefully guarded against if it is used.

Broadcast burning of heavy slash fuels has wide application in the heavy slash areas of the west coast and northern Idaho. Its use elsewhere is very limited.

It is a touchy method to use and demands careful preparation and follow-up.

Results of the practice continue to be controversial, and additional facts are needed to properly evaluate the results of such burning on soil, water, and vegetation.

Broadcast burning is used for hazard removal in blowdowns, concentrations of felled snags in old burns, removal of brush, and natural accumulations of fuels on the forest floor. The practice is quite well established in the south but is largely in the experimental stage in other areas.

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MAJOR TOPIC II - RELATION OF FIRE MANAGEMENT TO OTHER RESOURCE MANAGEMENT WORK.

Subtopic A - Integration and Correlation of Fire Control with Other Resource Management Work.

Item 3 - Water Management

By - Reed W. Bailey, Intermountain Forest and Range Experiment Station

Task Force Chairman - J. Herbert Stone

Acting Chairman - Kermit W. Linstedt

INTEGRATION AND CORRELATION OF FIRE CONTROL WITH WATER MANAGEMENT

Introduction

My first impulse upon being assigned this subtopic was to change the end of the title from "water" management to "watershed" management. I didn't obey that impulse because there seems to be about as much difference of opinion over the meaning of watershed management as there is over water management. Instead, I am assuming the two expressions are interchangeable and that they mean the handling of wildland resources within a watershed for the primary purpose of getting the most useful yields of water from the land. In keeping with this definition, my discussion will be concerned about fire control as a management tool for solving or at least minimizing downstream water problems.

In covering this subject I believe it is desirable to first spell out the kind of water problems with which watershed managers are usually confronted. This calls for an explanation of how watersheds function in general terms and for consideration of the probable limits to which runoff can be affected by fire control.

Unfortunately, quantitative data on the hydrologic consequences of fire are very meager. This precludes any attempt at this time to draw up detailed fire control specifications and standards for watershed management purposes. However, this need not and should not stand in the way of developing general fire control objectives and policies which are hydrologically sound.

A considerable body of information has accumulated regarding the runoff characteristics of the land and the manner in which watersheds function in receiving and yielding water. Here and there also are bits of evidence from controlled tests which indicate the probable limits to which some of the

important characteristics of runoff can be changed by land treatment. Though only part of this information is based upon studies of fire effects, they are worth considering because they point up basic principles which can be applied to fire control planning.

Water Problems

The water problems with which watershed managers are concerned fall into three categories. One of these is the amount of water that is yielded from the land either annually, or seasonally. Another is the maximum rate at which water is discharged to streams in relation to the capacity of channels to pass flows without causing damage. A third is the quality of water. This group may involve problems of unsatisfactory color, taste, odor, temperature, chemical content and bacterial count, though the most important aspect of quality is usually the amount of sediment carried by streams.

These three important characteristics of runoff--its quantity, rate, and quality--are affected by numerous watershed factors and hydrologic processes. These differ from place to place and in time. Consequently, some localities have too little water, some are frequently inundated, and some have poor-quality water. Moreover, it is not uncommon for a given locality to be plagued by all three kinds of water problems.

The watershed manager should have relatively little difficulty in establishing the existence and importance of the water problems in a given drainage basin. The evidence will be downstream. Water users will certainly know whether they have an adequate water supply and how much they can afford to pay for more water. Flood and water quality problems will have become a

matter of record or potential problems can usually be anticipated by comparing the questionable area with one or more comparable situations where water problems have developed.

It is now known that each of the important characteristics of runoff tends to be affected by a specific combination of watershed factors and hydrologic processes. It is also known that these critical combinations of factors and processes do not always operate in the same direction. For example, conditions which are conducive to increased water yields may also be favorable to increased peak-flow discharges and erosion. Conditions which are favorable to low sediment production may also be favorable to reduced flood discharges but may result in lesser amounts of runoff.

Determination of whether fire control can contribute to the solution of the downstream water problem or problems is a difficult task. That determination must be based upon a clear understanding of how watersheds produce runoff and a reasonable estimate of the extent to which fire control can affect the amount, rate, and quality of the runoff.

How Watersheds Yield Runoff

It is now known that the rain and snow received by watershed lands can be converted into two types of runoff. One type is commonly called overland flow because water reaches channels by moving over the surface of the land. The other type is sometimes referred to as seepage flow because water reaches springs, streams, and ground water basins by sinking downward between the soil and rock particles of the watershed mantle.

The conditions for producing overland flow are relatively simple. All that is required is that precipitation reach the ground faster than it can be absorbed. Rates of rainfall and snowmelt and the infiltration capacity of the mantle are, therefore, the major factors involved in this type of runoff.

For watershed lands to yield runoff as seepage flow it is necessary that the soil and rock mantle receive more water than it can hold against the force of gravity. The amount of precipitation is thus a primary controlling factor. Other critical factors include the amount of precipitation that is intercepted by vegetation and returned directly to the air by evaporation, and the storage capacity of the soil and rock mantle. The latter in turn is controlled in part by the depth, texture, and organic matter content of the soil and by the dryness of the soil within the root zone.

Overland flow usually contributes very little to the annual or seasonal amount of runoff because only the most intense portion of a rain is involved. The exception to this is on arid lands where overland flow may be the only type of runoff. Because overland flow reaches channels quickly, especially on steeply sloping areas, it can produce very violent discharges. This type of runoff also erodes and transports soil and is, therefore, capable of stepping up the sediment load of streams.

Seepage flow contributes to the amount of runoff to the extent that precipitation exceeds interception losses and mantle storage capacity. This type of runoff can contribute to floods, but discharges are generally much lower than those produced by overland flow because the delivery of water to channels is delayed. Seepage flow runoff is usually of good quality because

the water is filtered in its passage through the mantle. However, after reaching channels it has the capacity to erode and transport sediments.

These qualitative differences in the way overland flow and seepage flow affect the principal characteristics of runoff are of fundamental importance in the first appraisal of fire control needs as a watershed management measure. For realistic planning, however, it is essential that the probable quantitative effects on runoff amounts, rates, and quality be given more detailed consideration.

Water Yields

The average annual precipitation within the United States is known to range from less than 5 inches in parts of the Southwest and Intermountain regions to more than 120 inches in the Pacific Northwest. On lands receiving up to about 15 to 16 inches of precipitation practically all of the water is returned to the atmosphere from where it falls by the processes of evaporation and transpiration. These losses tend to increase with increased amounts of precipitation up to about 40 inches per year under warm and humid conditions. The difference between the amount of precipitation received and the amounts lost results on the average in less than 1 inch of runoff on the arid lands to more than 100 inches of runoff on the most humid lands (Fig. 1).

The annual runoff from a given area is apt to vary by as much as twice the average in wet years and by less than half the average in dry years. It is also characteristic for as much as 80 and 90 percent of the annual runoff to occur during a few months of wet weather and for only 10 percent to occur in the dry season.

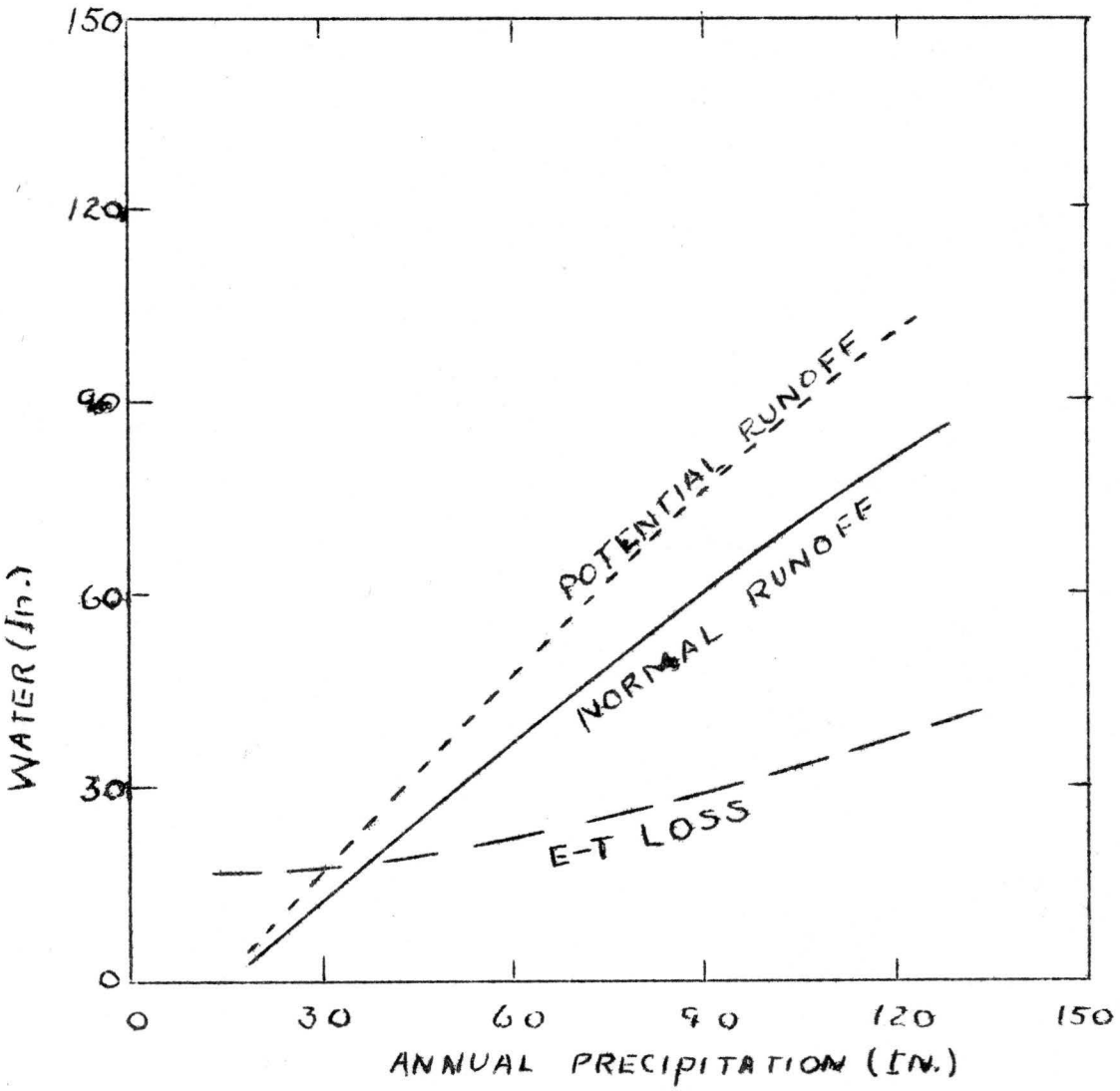

Figure 1. Approximate range of average annual water yields and evapotranspiration losses under natural watershed conditions and the potentials for increasing runoff in relation to annual precipitation.

These normal annual fluctuations and seasonal variations in water yields can be partially or completely controlled in some localities by construction of reservoirs. It is also possible to convey water from areas of surplus to localities in need of water by diversion works and canals. These possibilities should not be overlooked by watershed managers for they may well be the most effective way of solving water supply problems.

There are several ways, however, in which watershed managers can alter the amount of water that is yielded from the land by manipulating plant cover with fire. These possibilities can be most readily understood by considering some typical hydrologic situations.

Arid Lands. On arid lands--those receiving about 10 inches or less precipitation per year--fire control has but limited possibilities for increasing water yields. On such lands, the potential evapo-transpiration loss according to Thornthwaite (11) ranges up to 60 inches per year. This is far in excess of the precipitation received so that any alteration of actual evapotranspiration losses by fire or other means would be ineffective insofar as seepage flow yields are concerned. These lands, however, receive up to 1.00 or 2.00 inches of water during individual rain and snow storms. The rates of rainfall and snowmelt sometimes exceed the infiltration capacity of the mantle and thus result in some overland flow. The amount of runoff varies greatly from storm to storm but generally totals less than 1 inch per year.

Information on the direction and extent to which burning affects the small amount of runoff from these very arid lands is meager and largely untested. Some observations on blackbrush areas in southern Nevada indicate that the frequency and amount of overland flow is increased after such areas

are burned. The storms are usually localized. The runoff is generally flashy and laden with much sediment. Moreover, the relatively small amounts of runoff are frequently absorbed and dissipated in dry channels downstream. Burning is thus a questionable measure for getting more runoff from these lands.

There is another possibility of altering the availability of water in arid areas. That is by controlling evapo-transpiration losses along streams which traverse the desert areas. Robinson (10) recently estimated that there are about 15 million acres of phreatophytic vegetation in the 17 Western States and that the annual water loss on this area is between 20 and 25 million acre feet.

Considerable interest has been aroused over the phreatophyte problem especially over the possibility of salvaging some of the losses. After reviewing the findings on this problem, Colman (3) concluded: "So far no studies of phreatophytic water use have demonstrated how much water would be saved from evaporative loss by removal of the phreatophytic vegetation." He points out that if any water is to be salvaged from such areas it will have to be accomplished by drainage or pumping to lower the water table and by encouraging the replacement of such deep-rooted plants as salt cedar, mesquite, and cottonwood by plants with more shallow root systems. Fire could be used for destroying the undesirable vegetation, but other methods such as cutting, poisoning, and uprooting by heavy machinery appear to be more practical.

Semi-Humid Lands. The grasslands, pinyon-juniper, and sagebrush-bunch-grass areas of the West which receive from 10 to 20 inches of precipitation annually normally do not produce more than about 3 inches of runoff per year. All of this may occur as overland flow, especially on the driest of these lands, though a combination of both overland flow and seepage flow is more common.

There is very little quantitative data on the effect of fire on the quantity of either seepage or overland yields. In a study of natural lysimeters in Arizona having a soil mantle ranging from 3 to 6 feet in depth (9), depletion of the grass cover by grazing had no appreciable effect on seepage yields but stepped up overland flow. This resulted in an increased water yield of about 1 inch, but this was accompanied by greatly accelerated soil losses. Complete destruction of vegetation by fire conceivably might result in somewhat greater water yields but would probably also cause still greater erosion.

The possibilities of using fire as a means of destroying the relatively deep-rooted sagebrush, pinyon pine, and juniper and replacing those species with more shallow rooted grasses for the purpose of reducing the transpirational draft of soil moisture and thus increasing seepage flows is intriguing. Exploratory studies of soil moisture depletion at the Great Basin and Wasatch show that such measures, theoretically, hold promise of achieving increased water yields on the order of one or possibly two inches annually. However, such treatments also pose a threat of increased overland flow and sediment production, if the new cover is not well established before the next torrential rain.

It should also be possible to reduce the amount of water yielded from these semi-arid lands, especially during hard rains. This would require encouraging the maximum possible density of deep-rooted vegetation through complete fire protection, artificial reseeding, and supplemental mechanical aids such as water spreaders, contour trenches, and ponds.

Humid Lands. Forested lands and most rangelands which receive in excess of 20 inches of precipitation per year yield runoff predominantly as seepage flow. Several experimental tests on these humid lands have shown that depletion of plant cover by fire and other means can result in at least temporary increases in water yields.

The Wagon Wheel Gap experiment in Colorado is a classic example (2). This test involved two timbered watersheds where precipitation--mostly snow--averaged about 21 inches and runoff averaged about 6 inches annually. On one of the watersheds all timber was cut and burned. This resulted in an annual increase of 1.94 inches of runoff during the first year after cutting and a 0.67 inch increase in the seventh year. The average over a 7-year period was 0.96 inch. The bulk of this 16 percent increase was yielded in the spring

A burn in a ponderosa pine forest in southwestern Idaho, typical of lands which yield about 5 inches of water per year, appears to have increased runoff by about 0.5 inch per year.

Hoyt and Troxell (8) found that annual runoff of Fish Creek which drains a chaparral watershed in southern California, was increased by 2.5 inches in the year following the fire of 1924 but that the increased amounts diminished to 0.7 inch in the sixth year following the burn. The usefulness of these increased yields is questionable, however, since peak flows and sediment loads

were greatly increased, and 95 percent of the runoff occurred in the winter rainy season when it could not be put to beneficial use downstream.

Croft and Monninger (5) deduced from soil moisture studies that about 4 inches more water per year was available for seepage flow runoff when deep-rooted aspen trees were removed from plots in a 51-inch precipitation zone on the Wasatch Mountains in Utah. They also found that another 4 inches of water was available for streamflow by completely denuding aspen plots through cutting and burning. The latter treatment, however, resulted in terrific soil losses and overland flow.

Wilm and Dunford (13) demonstrated that removal of all merchantable lodgepole pine timber on plots near Frazer, Colorado, increased the amount of water available for streamflow by about 3.0 inches. This 31 percent increase was due mainly to a reduction in interception of snow. The cutting operation involved only merchantable timber and did not cause much soil disturbance. Though fire was not involved in this experiment, the results are cited to illustrate the potential effects of reducing interception losses in coniferous stands where runoff is derived mainly from snow.

Clear cutting of all hardwood trees and understory on a 33-acre watershed at the Coweeta Experimental Forest in North Carolina resulted in a 16.7 inch or 60-percent increase in annual runoff during the first year after cutting and about a 200-percent increase in flow during July (7). During the first year, all sprouts were cut. In the second year when sprouts were not cut, the increased annual runoff was on the order of 30 percent. This test is mentioned to indicate the probable upper limits to which yields of runoff can be increased in the humid Southeast where rainfall may total up to 85 or 90 inches per year.

The extent to which removal of riparian vegetation in humid regions can step up annual and seasonal yields has not been determined accurately. A 10-day test at Coweeta (6) showed that daily flows in the summer increased about 12 percent immediately after cutting. Such an increase could be of considerable economic value in seasons of low flow but the practicability of using fire to destroy the riparian vegetation remains to be determined.

The foregoing evidence clearly indicates that removal of vegetation whether by fire or other means tends to increase the annual and seasonal amounts of runoff. Percentage-wise, these increases may amount to as much as 60 percent in very humid areas and 100 percent in arid areas for a year or so immediately following complete denudation, with lesser degrees of plant cover removal giving immediate increases on the order of 30 to 10 percent or less. These effects are likely to diminish annually to virtually zero over a period of 5 to 15 years, depending upon the rapidity of natural revegetation. Unless action is taken to maintain the plant cover in a depleted condition, the average annual increase in water yields over a period of years is, therefore, more likely to be on the order of 10 percent or less.

Peak Flows

Peak-flow discharges can be generated by runoff that occurs solely as seepage flow, as overland flow, or by a combination of these two types of runoff. It is not always possible to separate the contribution of each type of runoff to a particular flood. On the other hand, from observations on the ground, it is known that very little overland flow takes place during some floods, such as those which develop from prolonged gentle rain and from prolonged, slow snowmelt, and that in other instances sudden rises in

streamflow can be attributed almost entirely to the quick delivery of water to channels by overland flow. These two types of floods warrant separate consideration because they differ greatly in the degree to which they can be affected by changes in the vegetation on watershed lands, especially by fire.

Seepage Flow Floods. Numerous factors contribute to the peak-flow discharges generated by runoff that occurs predominantly as seepage flow. Assuming essentially normal plant cover conditions, these factors include the size and shape of the watershed, the storage opportunity in the mantle, the water transmission capacity of the mantle, and the amount of water that is released from a snow pack or the amount of rain that occurs in a storm period. When all of these factors, except precipitation, are constant, the magnitude of seepage flow floods tends to increase with increased amounts of precipitation. Thus, in semi-arid regions maximum peak discharges are usually within the range of 10 to 30 cubic feet per second per square mile of watershed area (c.s.m.); whereas, in humid areas the peaks may be on the order of 100 to 400 c.s.m. (Fig. 2).

In the humid hardwood forests of the Southeast it may be possible to cut down all trees and brush without causing an appreciable increase in seepage flow peak discharges, provided the cut material is left on the ground as a mulch. This was demonstrated in one of the tests at the Coweeta Experimental Forest previously referred to, but did not involve burning. Elsewhere in the South, light burning is considered a necessity for the healthiest growth of longleaf pine. Where this type of burning has been done on

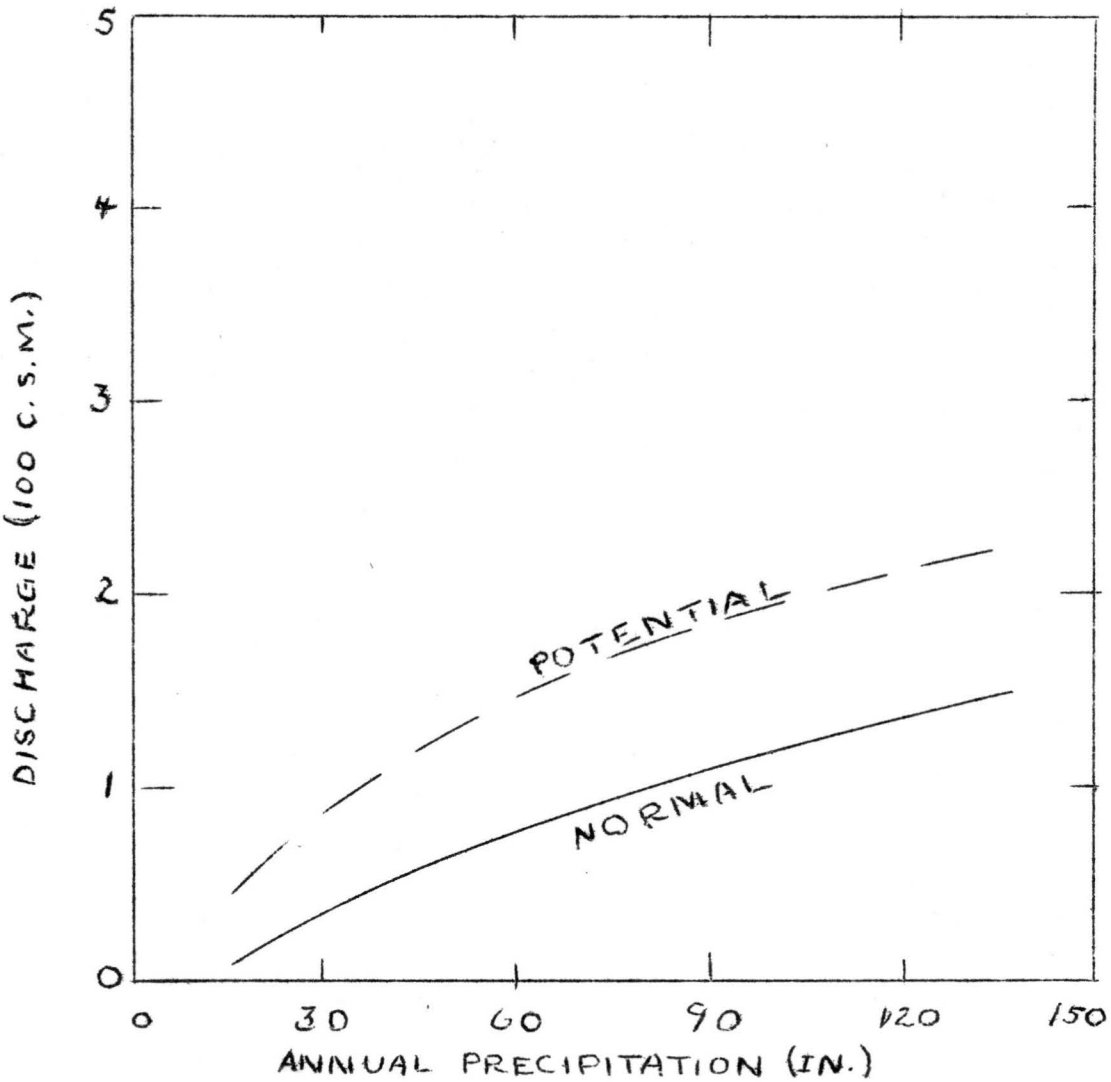

Figure 2. Approximate range of normal seepage flow discharges and the potentials for greater discharges in relation to annual precipitation.

relatively flat slopes, there has been no apparent effect on flood peaks. Where such fires result in substantial loss of litter and organic matter in the soil and a consequent reduction in water storage capacity, however, they could result in faster delivery of water to streams.

Such effects can almost certainly be expected where fire destroys the plant cover as well as the litter on the ground. In the Wagon Wheel Gap experiment previously referred to, peak flows following burning were increased by about 50 percent. In the case of the 1924 Fish Creek burn in California, peaks during the next few years were increased by 100 to 225 percent, though part of these floods no doubt occurred as overland flow.

There are some circumstances in which fire might be used to reduce seepage flow floods. Where previous fires or other causes have resulted in the establishment of relatively shallow rooted plants such as cheatgrass on natural sagebrush-bunchgrass range, fire may be used as a tool along with reseeding to reconvert the area to more deeply rooted perennial plants. These plants, by extracting soil moisture to greater depths, should provide more storage opportunity and thus result in both less total runoff and lower seepage flow peaks. Brush burning to reestablish a forest cover also should eventually have the same effect, but because of the slow rate at which conifers grow, it is more likely that increased discharges will occur until the volume and density of the tree crowns exceed the interception capacity of the brush.

Overland Flow Floods. The two most important factors contributing to the occurrence of overland flow are precipitation rates and the infiltration capacity of the mantle. The latter is controlled fundamentally by the

porosity of the soil but is also markedly influenced by the amount of plant and litter cover. On areas which have a complete plant cover and well developed soil, overland flow may never occur or, if it does, in only negligible amounts. On sites with decreasingly less amounts of plant cover and less soil development there is a tendency for overland flow to increase. On completely bare, steep slopes overland flow may generate discharges up to as much as 5,000 c.s.m. (Fig. 3).

The manner in which the thinning or destruction of vegetation and litter by fire or other causes leads to the occurrence of overland flow is now rather widely known and need not be elaborated upon here. The potentialities for increasing overland flow discharges, however, are not so well known or appreciated.

On areas which are naturally barren or sparsely covered, the potential for increasing overland flow is relatively small. On such areas the frequency and magnitude of the discharges are largely a function of the frequency and intensity of precipitation. On areas with increasingly greater amounts of plant cover and deep soil, the potential for overland floods is very great, especially in regions that are subject to torrential rains and where slopes are steep.

The magnitude of this potential is illustrated in the runoff behavior of two watersheds in the Davis County Experimental Watershed in northern Utah. Here the densely covered Morris watershed has produced virtually no measurable quantity of overland flow even during rains which attained rates in excess of 5.00 inches per hour for brief periods. The nearby halfway watershed, with depleted plant cover in its headwaters, has produced floods during the same

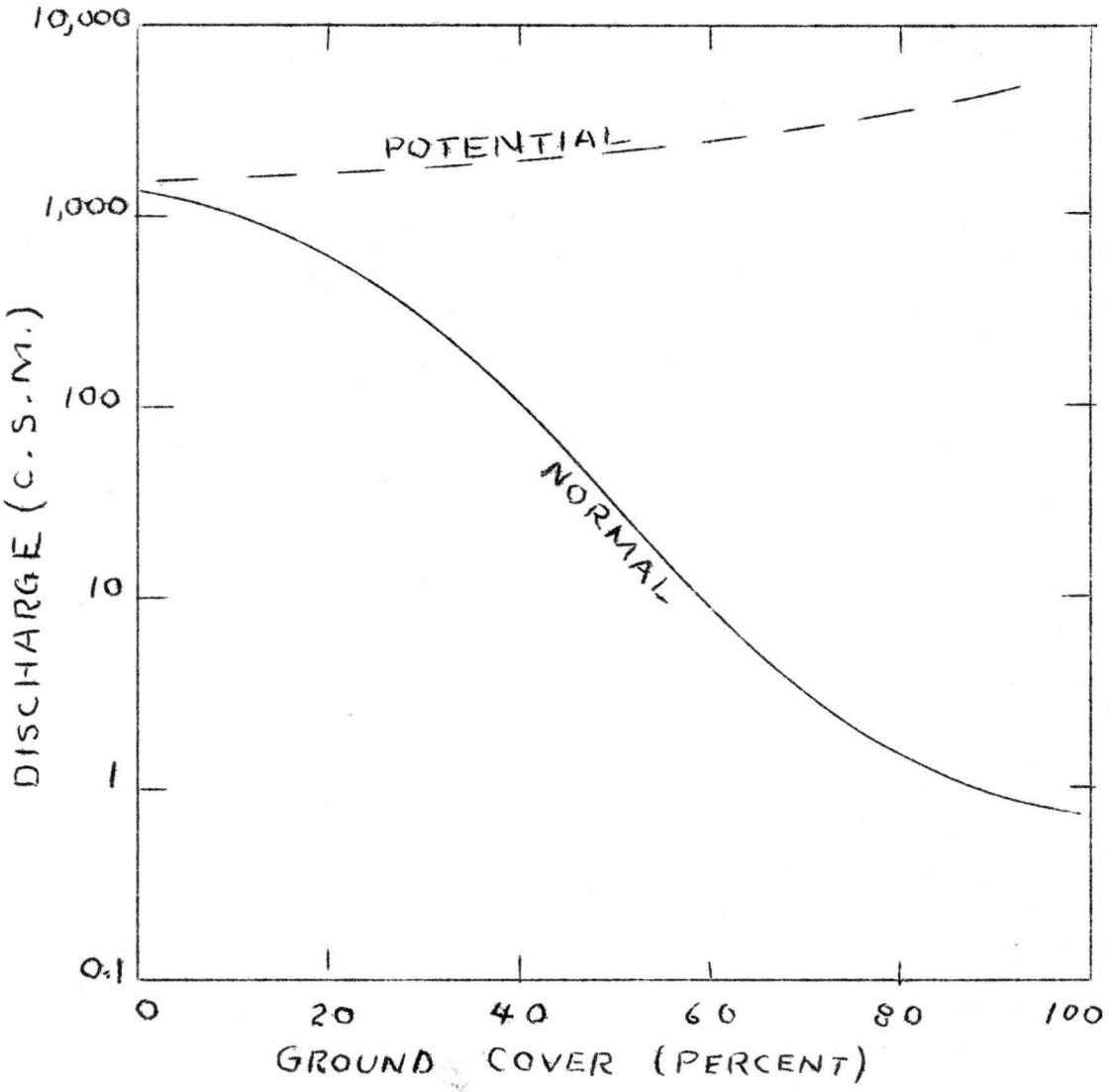

Figure 3. Approximate range of normal overland flow discharges and the potentials for increased discharges in relation to the amount of plant and litter cover.

storms that attained discharges which are estimated to have exceeded 2,000 c.s.m. The total volume of rain during these storms was only about 1 inch. Similar floods from similar rains were generated in other watersheds in that locality after plant cover had been depleted by fire and overgrazing on areas which in the aggregate totaled less than 10 percent of the drainage area (1).

The hazard for greatly increased flood discharges following hot fires exists in virtually all regions of the United States where steep slopes are subject to torrential rains. Where these conditions prevail, the degree of the fire-flood hazard depends upon the frequency at which severe storms occur and the rate at which the burns revegetate. Thus, the potential effects of relatively frequent torrential rains in the Southeast are substantially offset by rapid regrowth. Slower regrowth and a relatively frequent incidence of major winter storms make the fire-flood threat especially serious on the brushlands of California (12). The foothill lands adjacent to Salt Lake City were burned on numerous occasions over a period of nearly 100 years before there was a coincidence of a hard summer rain within a year following a fire. That coincidence resulted in a major flood during which discharges developed on the order of 4,000 c.s.m. (4).

Though fire control planners have or can obtain reasonably good estimates of the rate of revegetation and the average incidence of major storms for a given locality, they will always be faced with the possibility of having a major storm occur before the burned area is adequately covered. The probable consequences of such a coincidence should be carefully considered in planning for the control of wild fires.

On areas where damaging overland flow has already been stepped up by fire or other watershed abuse, tight fire control may be all that is needed for rapid revegetation. Where the rate of plant recovery is slow in relation to the incidence of severe storms, however, it may be desirable to supplement fire control with reseeding, planting, and such mechanical aids as contour trenching to hasten the control of overland flow. Sowing of mustard seed has been found to provide at least partial control of runoff on burns in California. Sowing of perennial grasses has been found to be effective for restoring the control of runoff as well as the forage production on many burned ranges. Tree planting will also provide control, but usually not for several years. Virtually complete control of storm runoff was accomplished on the Davis County Experimental Watersheds by supplementing fire control, exclusion of livestock grazing, and grass reseeding with contour trenching.

Tight control of wild fires need not preclude the use of fire as an aid in improving the control of overland flow on areas where less effective plant cover has become established. Much heat has been generated over the brush - burning problem in California. Much more needs to be learned about it. There appears to be no room for argument, however, that fire can be used on some brush sites provided the burning is followed by seeding and careful grazing use. Fire has also been found to be an efficient means of clearing sagebrush, oakbrush, and even juniper where it is followed by seeding to perennial grasses. Such treatments, however, always pose the risk of having potent storms strike the burned area before the new plant cover becomes fully established.

The foregoing evidence shows that fire is almost certain to be followed by increased rates of runoff, especially if more-than-average amounts and rates of precipitation occur before the plant and soil mantle is restored to normal or near normal conditions. The potential increased rates from seepage flow discharges appear to be within the range of 100 to 200 percent, whereas, overland flow discharges may be increased by as much as 1,000 times. Fire control can prevent the occurrence of these potential discharges. Controlled burning, on the other hand, can be used under certain circumstances to improve the control of runoff by aiding in the establishment of more effective plant cover conditions.

Water Quality

The sediment load carried by streams has long been recognized as being one of the most serious aspects of the problem of water quality. Its presence necessitates costly filtering plants when water is used for domestic and most industrial purposes. Dredging is necessary where it shoals harbors and reduces the capacity of channels to carry flood flows. It necessitates costly canal and ditch cleaning, and it shortens the useful life of reservoirs.

The amount of sediment carried by streams rests, fundamentally, upon the stability of the soil and other mantle materials on watershed slopes and upon the stability of stream channels. The stability of channels is largely a function of streamflow velocities. The rates at which water is discharged to channels from the land as well as the stability of watershed slopes are in turn substantially influenced by the amount of plant and litter cover.

The role that vegetation plays in controlling erosion is now well known. Vegetation and litter prevent or minimize the detachment of soil particles

by shielding them from the impact of raindrops. By fostering infiltration and impeding the flow of water over the surface, vegetation also minimizes the transport of eroded materials. These effects of vegetation can produce almost complete stability even on very steep slopes, where the soil is completely covered by vegetation, and they become decreasingly less effective as the amount of plant cover diminishes. On completely vegetated areas, sediment production may be as low as 0.0001 acre foot per square mile of watershed per year; whereas, on naturally barren areas having soft rock, such as some of the badlands and parts of the Colorado River watershed, the rates may be on the order of 6 to 10 a.f. per square mile per year (Fig. 4).

The problem of muddy water can sometimes be traced to areas where the normal rate of erosion is high because of unfavorable conditions for plant growth. Typical of such problem areas are some of the arid and semi-arid lands of the West. The extent to which fire can be used to lessen sediment production on such areas has received very little attention. The possibilities lie in the same direction as those for reducing storm flow runoff; that is, as an aid in replacing widely spaced and tap-rooted plants with species which either produce more dense cover or a more fibrous network of roots near the soil surface. Water spreaders, gully plugs, and similar mechanical controls of runoff will probably be more effective for this purpose.

The principal concern of fire control planners in most areas, however, will be the problem of preventing fires that lead to accelerated erosion and increased sediment production. The vulnerability of areas to accelerated erosion is about as variable as their susceptibility to produce overland flow. In other words, on areas where rains are gentle, gradients are low,

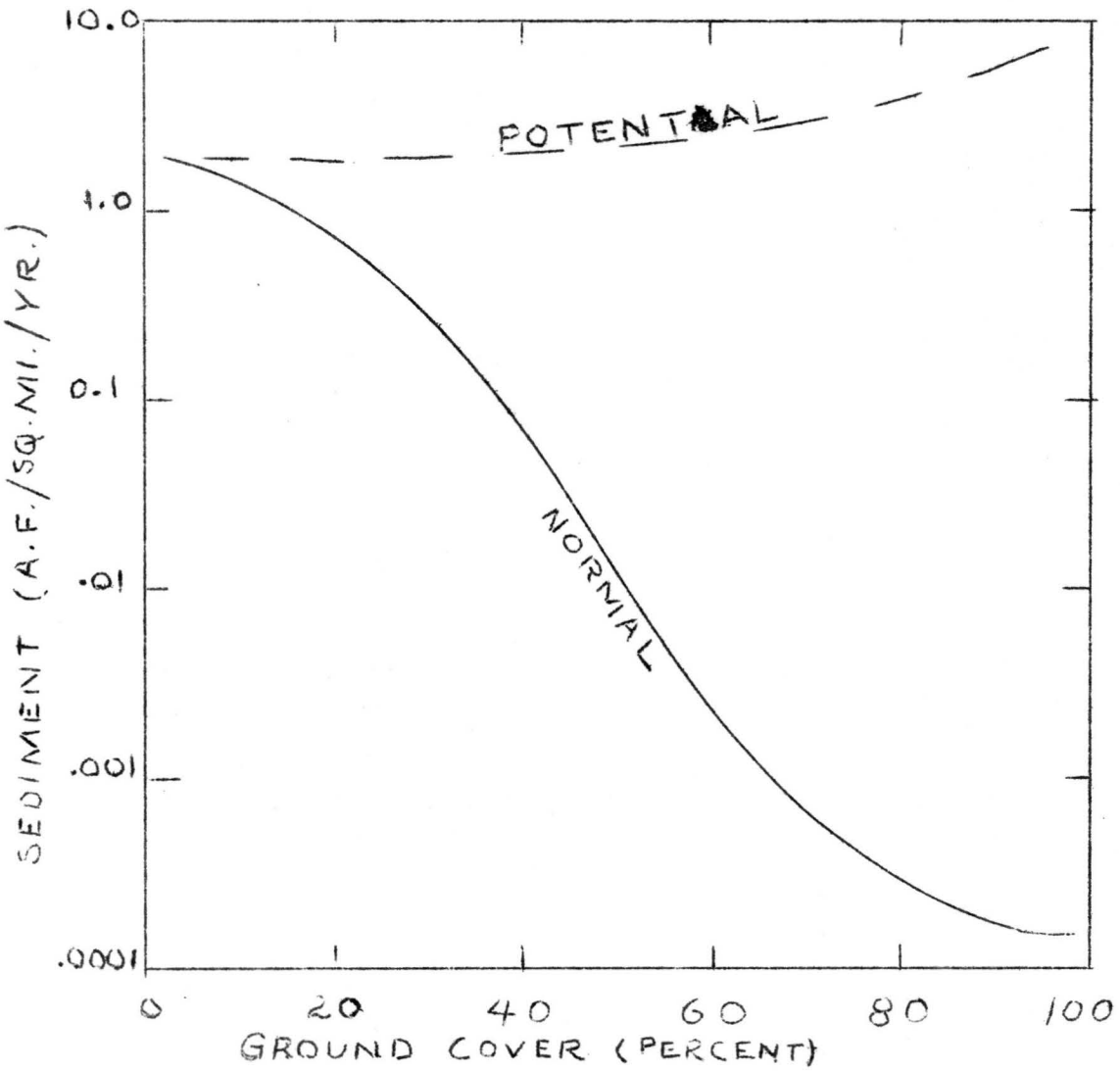

Figure 4. Approximate range of normal average annual sediment production and the potentials for increased sediment production in relation to the amount of ground cover.

the soils are porous, and revegetation is rapid, the hazard of accelerated erosion is low. Conversely, the sediment-production potential on areas subject to torrential rains and especially those having steep slopes and deep accumulations of soil, is very high. On such areas, the complete removal of plants and litter can result in stepped-up sediment production rates which are not apt to be in terms of percent but rather in terms of several thousand times the normal. For example, the annual sediment-production rate from the previously mentioned well-covered Morris Creek watershed in Davis County, Utah, is about 0.0004 acre foot per square mile. Other watersheds in that locality which formerly also produced very small amounts of sediment are now, after being depleted by fire and overgrazing, producing at rates up to 2.5 acre feet per square mile, or 6,000 times faster than Morris.

The tremendous potential for accelerating erosion on the land is only one aspect of the sediment-production problem. When smooth soil surfaces are incised, even by shallow rills, it takes less and less rain to produce increasingly violent discharges of overland flow which can add more sediment to the water by scouring the downstream channels. Much the same effect can result even in areas of gentle rain and slow snowmelt when smooth slopes are cut by gullies which permit the quick bleeding of seepage flow runoff. The maintenance of soil stability is thus a primary requirement not only for keeping streams clear but also for preventing abnormal floods.

Objectives and Policies

The foregoing considerations of the hydrologic effects of fire suggest that fire control planners must make a choice in selecting their watershed management objectives. The three possible choices are (1) to improve or maintain water quality, especially in terms of sediment production; (2) to prevent abnormal floods, and (3) to increase the useful amount of runoff.

The requirements for minimizing sediment loads and floods are essentially similar. They include the maintenance of the greatest possible stability of soil and the greatest possible amount of vegetation and litter. The kind and amount of vegetation and soil which have developed under undisturbed conditions provide the best criteria for adopting site-by-site fire control goals. Where wild fires or other abuses have already accelerated erosion and stepped up floods or where there is a good chance that a severe storm will occur before natural revegetation can provide effective control, provision should be made for the quickest possible revegetation of those areas by seeding, planting, and supplementary mechanical measures.

More water can and will be yielded by lands when the plant cover is destroyed or substantially thinned by fire or other means. The adoption of such an objective, however, must be weighed against the possibilities of increasing both flood peaks and sediment yields.

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MAJOR TOPIC II - RELATION OF FIRE MANAGEMENT TO OTHER RESOURCE MANAGEMENT WORK.

SUBtopic A - Integration and Correlation of Fire Control with Other Resource Management Work.

Item 4 - Inaccessible Areas - Wilderness, wild and primitive areas.

By - A. E. Spaulding, R-1

Task Force Chairman - J. Herbert Stone

Acting Chairman - Kermit W. Linstedt

INACCESSIBLE AREAS - WILDERNESS, WILD, PRIMITIVE AND ROADLESS AREAS.

Back-country areas in all regions present difficult problems in fire control, mainly due to slowness of ground travel. Fire occurrence, topography, fuels, weather factors and values vary considerably and each such area has its own particular problems. In presenting this subject I have largely confined my remarks to the Selway-Bitterroot and Bob Marshall Wilderness Areas in the Northern Region. In the discussion that follows, we can bring out the fire control problems in roadless areas in the other regions.

Fire control has not been solved in these roadless areas. The job is costly.

Fire suppression costs in 1953 averaged 15¢ per acre in the Bob Marshall and Selway-Bitterroot Wilderness Areas. Detection, prevention and preparedness cost about 6¢ per acre. Burned area was 2,169 acres from 216 fires. Area burned was less than 1/10th of 1 percent, and acceptable from a resource viewpoint, but costs were sufficiently high to emphasize the need to search for more economical ways to handle the fire problem in roadless areas.

The 1953 occurrence maps show an impressive plastering of fires on the Selway-Bitterroot Area and a mere spattering on the map of the Bob Marshall Area. Overlays for the fire year period 1936 to 1940 indicate a consistent high occurrence on the former and occurrence on the Bob Marshall up and down with some seasons almost a blank. Number and distribution of fires affect the organization, but burned area is a better measure of resource damage. Burned area appears to provide the best available measure of past performance and future potential. The overlays and following tabulation illustrate this point:

	Annual Average Area Burned	
Period	Selway-Bitterroot	Bob Marshall
1901-1910	22,704	17,982
1911-1920	5,501	1,075
1921-1930	5,982	2,431
1931-1940	15,311	457
1941-1950	Negligible	Negligible
1953	1,398	771

By reference to the overlays it is evident that a few bad seasons in this recording, namely 1910, 1919, 1929, and 1934, produced burns sufficiently extensive to be unacceptable. However, in these and other back-country areas, there is much evidence of older repeated and disastrous burns not shown on our maps.

Disastrous fires have not occurred in these two areas for nearly two decades (since 1934). Great strides have been made in early concentration of strength on threatening fires in our back country during recent years, but we cannot say that the protection problem has been solved in inaccessible areas. I do not believe weather factors have combined during this period to produce a "conflagration year" similar to the bad seasons mentioned above. In 1953 these back-country areas were much drier than normal, but extreme burning conditions did not extend into sufficient continuous periods to be classed as a "conflagration year". This year we had an all-time record number of lightning fires during the month of August and experienced a demonstration of the vulnerability of our back country, once we run out of smokejumpers and have to go back to the old foot-slogging methods. This was the first time since the loss of the CCC's and pre-war labor conditions, that a serious fire situation developed in the wilderness areas. Time and again in previous recent fire seasons, we have used the last available smokejumper or airplane, but never experienced the shortage of this year. We knew from a study of past fire history that our force of 150 jumpers was adequate to take care of only 6 years out of 20 and that 200 would handle 11 years out of 20, further that 240 are needed to insure a safe margin that would give us reasonable assurance of weathering a season like 1953 without excessive suppression costs. The Tango Creek fire in the Bob Marshall Wilderness Area cost $94,000 to suppress. This fire involved a 17-mile hike over a high divide from the road-end. An adequate force of jumpers would have saved a large part of this cost. That fire and four others with

similar circumstances, cost a total of $328,000. An analysis covering all areas of heavy smokejumper use indicates that, if an additional 90 smokejumpers had been available, we would have had a probable saving of $633,400 in suppression costs and $63,500 in damage. This figure does not include many of the smaller fires that were not analyzed. We had 132 instances during the season where requests for jumpers were turned down because none were available. The 90 additional jumpers, needed to meet the requirements of 1953 and similar serious but "non-conflagration" years, would have cost $115,000.

Our 1953 fire season history provides evidence that the job of protecting these roadless areas is still not solved and in addition we have the problems of the occasional "conflagration year" to contend with. The real threat to the practice of forestry in Region 1 is the "conflagration year," and protection should be such as to keep burned area during these years within acceptable limits. If this is done, there will be no significant losses during the easy years.

Benefits from fires in wilderness areas and the damages as related to water yield, sediment production, recreation, and other.

The roadless areas in Region 1 are in the headwaters of the Missouri and Columbia Rivers and are vitally important from a watershed standpoint. Their primary use is water production. Quality, quantity, and timing of water flow are important.

Reference to the Region 1 map showing location of reservoirs and dams pictorially indicates the local importance of water from the national forests. The downstream water use and need for controlled water flow are even more important.

The designation of wilderness areas was primarily for recreation use. Watershed and wildlife values were secondary. Increasing population in the West does and will require more and more water and better control of water flow. This need, along with continued construction of power, flood-control, and irrigation dams and bettering of soil conservation practices has greatly increased watershed values and it is now of primary importance.

Hungry Horse is one of the more important dams in the area. Statistics follow:

Drainage: 1,015,192 of which 610,000 acres are within the Bob Marshall Wilderness Area.

Flowage: 22,500 acres.

Storage: 3,500,000 acre feet.

Will irrigate: 45,000 to 75,000 acres.

Will generate: 300,000 k.w.

Construction cost: $102,000,000.

Will provide flood control for downstream areas and will provide additional flow in Columbia during short-water months for this vastly increasing downstream power production during previous low-water periods.

A dam above Kooskia, now proposed for construction, will use all the water from the Idaho site of the Selway-Bitterroot Wilderness Area.

The investment in Hungry Horse Dam amounts to $100 per acre of drainage above the dam. If the reservoir were allowed to fill with silt from burned areas, the loss would be more than $100 per acre as a replacement in kind would be much more expensive.

In planning for management of water, we should know whether the objective is (a) simple control of run-off damage, or (b) production and control of maximum available water for use. Authorities appear to agree that full forest cover gives best results in control of run-off damage, permitting maximum loss by evaporation (mostly transpiration) and distributing run-off. For maximum controlled production, they favor well-distributed small openings. Localized research is needed to determine what comprises good watershed management.

Roy Headley made the statement a number of years ago that "fire effects on watershed damage for the country as a whole far exceeded fire damage to merchantable timber despite the fact that fire has little effect or none at all on many watersheds." An important chain of facts on watershed damage is the samll percentage of total precipitation which is captured for human use. The quantity of water removed from inland areas through evaporation and transpiration ranges from about 50 to 95 percent, and averages approximately 70 percent of precipitation in such areas. The ideal economy of quantity of surface water would be

served by adequate reservoir storage below paved watersheds. This would cut off the loss by tranpiration and reduce evaporation to little more than that from the surface of a reservoir and would multiply several-fold the actual surface yield of water. This heavy loss by evaporation and transpiration means that, when adequate reservoirs are provided, there is no damage from fire to quantity of water yield when all of this water is needed and can be held in surface storage. The damage is then confined to the filling of reservoirs by silt and debris released by erosion following the fire. The damage from fire-loosened debris can be very large. Some watersheds, if burned over, would produce more debris than others because of the erosion coefficient of the soils and other factors. We need to know more about this.

Because of the need to prevent siltation of reservoirs, we must maintain good fire protection in their drainage areas. This in turn does not release the maximum quantity of water as would denuded watersheds, and consequently, we do not need adequate reservoir storage to meet such maximum flow. I am confident that the most economical end result will be a combination of well-managed watersheds, coordinated with a minimum number of storage reservoirs to meet needs area by area.

The effect of fires on underground storage and water tables in most cases would be detrimental. Generally less water will percolate into the ground on burned areas than on areas with a forest cover. Bare-surface material may be so sealed by muddy water that heavy flows may pass over it with little effective percolation. The detrimental effect on wells, springs and irrigation-water supplies even at some distance, may be important.

Need for fire protection of watersheds, now vitally important, is increasing as we make inevitable progress in water management.

Recreation

Damages to recreation include:

Detrimental effects on pleasure, aesthetic values and inspirational influences recreationists derive from unburnt cover, including freedom from interruptions of recreational activities; detrimental effects on current recreational business income; depreciation of investments in structures for recreational purposes because of fire damage to cover, scenery, etc.

The above particularly apply to fires in the limited areas used by recreationists. Burned areas at a distance from a trail may not be too harmful from an aesthetic standpoint except that repeated fires during the recreation season would influence people not to use the area.

Benefits to recreation include:

Limited burned areas in unbroken forest cover may be beneficial to provide a change in scenery.

Wildlife

Fire damage or benefits to wildlife relate to cover and food. Where there is not enough cover, good fire protection is needed. Where there is too much cover, fire can be a benefit. Much of our big-game range in our roadless areas was created by large fires. We now have talk of the need for more burned area for game where fire control has been effective. In some areas the browse is too high to be reached by game and it has been advocated that burning such areas will cause sprouting of browse and thus produce reachable feed. Also in areas that have a closed canopy of green timber and there is no feed, burning might create openings that would produce browse. Both of these conditions apply to winter game range as the summer supply of game food generally exceeds the carrying capacity of the available winter food supply.

Fish food is unfavorably affected by the ashes, scouring, and accelerated erosion which are likely after burning. Fire may also kill the trees along streams and destroy the shade needed by fish. Fires may also damage the supply of birds and minor fauna.

Other damages that may result from fires in wilderness areas include increased cost of protection - where single burns in mature timber increase the fuel ratings for a period of years. Also fire-weakened trees may contribute to tree-killing insect epidemics.

Other benefits may result - where a burn cleans up bad fuel messes and lowers the fuel ratings, thus lessening the cost of fire control.

Should prescribed burning be a part of management of such areas?

Records show that the fuels in Region 1 classified as H-H and worse, comprised less than 6 percent of the area protected by the ten western forests from 1931 to 1943. Yet during that period these bad messes of fuels were responsible for no less than 55 percent of the area burned.

Comprising about 13 percent of the area protected, the H-M and M-H fuels, which are worse than the average for this region but which are not as menacing as the H-H and worse fuels, had only one-eighth as much influence on the area of burn.

The reduction of bad fuels can benefit fire control only through its effect on the area of future burn or, in other words, by lowering the sum total of fire control cost plus fire damage.

In Lyman's "Principles of Fuel Reduction," published in March 1945, I have taken the following "Outline of General Situations Where Different Intensities of Fuel Reduction Are Likely to be Most Economical":

II. Noncommercial forest lands, including Primitive Areas

A. All timber types

1. Reduce 85 percent or more of bad fuel areas meeting the following requirements:

a. H-H and worse fuels that nature will not reduce to less than H-H by 1950.

Cost of fuel reduction - less than $15 per acre.

Barriers - fuel bodies NOT adjacent to barriers which would prevent a fire from burning more than 5,000 acres.

(90,000 acres to be reduced.)

b. M-H fuel types that nature will NOT reduce to less than M-H by 1950. And H-H and worse fuels that nature WILL reduce to less than H-H by 1950.

(1) Wildlife habitat - big-game winter range where utilization of forage is impeded by fuel mess.

Height of reproduction - less than 20 feet.

Size of area - any.

Regeneration of vegetation - palatable browse shrubs will restock adequately by natural processes after fuel reduction.

(10,000 acres in Lochsa and Selway River country.)

(2) Wildlife habitat - not big-game winter range.

Height of reproduction - less than 15 feet.

IF 300 or more trees per acre, evenly distributed.

Size of area - 1,000 acres or less.

Adjacent values menaced - (for minimum requirements, see following table):

Cost of fuel reduction (per acre)	Size of bad fuel area		
	100 acres	500 acres	1,000 acres
	Minimum area that must be menaced (sq.mi.)		
$ 5	12	30	50
10	25	60	100
15	35	90	not justified
20	50	120	" "

(15,000 acres to be reduced in Region 1.)

c. H-M fuel types that nature will not reduce to less than H-M by 1950.

Size of bad fuel patches - 1,000 acres or less.

Any condition of site, artificial regeneration, etc.

Adjacent values menaced - very high values in improvements aesthetic or recreation, and in accordance with table above. (8,000 acres to be reduced.)

2. Reduction of less than 85 percent of bad fuel areas by reducing 1/2 to 1 1/2-mile-wide strips strategically located.

The following fuel types not included in above classifications:

M-H fuel types that nature WILL NOT reduce to less than M-H by 1950.

H-H and worse fuel types that nature WILL reduce to less than H-H by 1950.

Height of reproduction - less than 15 feet IF more than 300 trees per acre.

Size of bad fuel patches - 1,000 acres or more.

Adjacent values menaced - see table:

Cost of fuel reduction (per acre)	Size of bad fuel area			
	1,000 Acres	2,000 acres	4,000 acres	5,000 acres
	Assumed acreage to be reduced			
	600	800	1,200	1,500
	Minimum area (square miles) that must be menaced			
$ 5	60	70	80	100
10	120	140	160	not justified
15	180	not justified		not justified

(20,000 acres to be reduced)

Summary of above areas proposed for fuel reduction, amounts to 143,000 acres. At a conservative estimate of $10 per acre, it would require $1,430,000 for adequate fuel reduction in the roadless areas of the ten western forests in Region 1.

A summary of proposed fuel reduction areas on commercial timber land and of higher priority than the above, due to a higher cost-plus-benefit ratio, amounts to 443,000 acres. At a conservative cost of $20 per acre, the estimated total is $8,860,000. Since Lyman's study was made, nature has reduced the fuel ratings to a considerable extent, especially in 1926 and previous single burns. However, on the debit side we have new high hazards on huge areas of blowdown and will have many new snag areas following current insect epidemics.

A generalized conclusion is that for economic reasons we would reduce the fuels on classifications of commercial land prior to embarking on a sizeable program in the roadless areas. Sufficient funds are, therefore, not likely to be available for such a program in the wilderness areas. Prescribed burning in wilderness areas in Region 1 on a scale that would result in lowered protection costs will probably not occur and we must look principally to other means for reduction in costs.

We should, however, continue to consider important problem cases and we will be doing some prescribed burning on a planned basis in roadless areas such as:

1. For fuel-reduction purposes on critical areas as opportunities afford, conditions are ideal, and qualified personnel are available.

2. For the control of forest-destroying insects.

3. For improvement of habitat on critical big-game winter range.

4. As quantity of water becomes critical in the future, we may use fire to purposely create openings to increase available supply of surface water.

Should we set up different suppression policies and burned-area objectives for the roadless areas?

The suppression policy (so-called 10-o'clock policy) as now written in the Manual, is satisfactory for roadless areas and should not be changed until some better policy is adopted for national forest land. Controlling fires while they are small or, failing in that, attempting to control them early, has proven in Region 1 to be economical in suppression cost plus resource damage.

Considering the high water production ($3\frac{1}{2}$ acre-feet annually per acre), damage, if watersheds are mismanaged, and high cost of suppression for the few project fires not handled by aerial control forces, we would not want any de-emphasis of the policy asking for early control at small acreage. Priorities on use of available forces during overload periods may call for delayed action on fires in accessible areas provided such fires do not have more important potentials for damage and suppression costs.

In comparison with acceptable minimums for accessible fires, higher quality manpower is needed to hike long distances into back-country fires to be effective upon arrival. Good suppression planning should always recognize this fact even though it may delay getting adequate manpower on the fire. As I interpret our suppression policy, this procedure is encouraged.

A fire suppression policy that did not require fast, energetic, and thorough suppression action would place us in an untenable position. Except as a last resort, we should never degenerate to a fire-herding policy as it is fraught with dangers. Every project fire of any size is highly publicized. A relaxing in suppression policy would result in much criticism. We have, in the West, advocators of burning - much of which could be harmful. Relaxing protection in the roadless areas would give these "burners" additional ammunition that could have far-reaching detrimental effects. Smoke from wilderness-area fires might also impede air transport and defense of the country, and make detection of fires in adjacent areas more difficult.

Burned-area objectives are not too important as long as we maintain our present suppression policy. If any changes are made, I believe we should give more consideration to the high cost of suppressing project fires by ground forces in the roadless areas. This would, in some cases, reduce the objective to a smaller percentage. More consideration of suppression costs may help us get away from some of the undesirable implications of "acres of ashes" as a measure of fire business.

Do we need to consider other things than men, trails, airplanes, smokejumpers, etc., in protecting our roadless areas?

Devices or methods by which threatening fires could be slapped down or slowed up would indeed be welcome. Spraying with fire retardants from airplanes or helicopters on a selected basis has some promise, especially if we can obtain cooperation of the Department of Defense. It is encouraging to note that experiments continue.

Weather modification to produce precipitation and/or reduce the number of lightning strikes also has possibilities. Research projects now underway will soon give us additional information on this subject. This project may also help in providing better long-range fire weather forecasts which would indeed be valuable to the fire control administrator in making advance preparations and, if properly used, they would help reduce the over-all fire control cost plus damage.

Development of light power equipment holds considerable promise. Line-clearing equipment, commercially available, such as chain saws, scythettes, sawdettes, are a help. We do not need special development work for falling and bucking as commercial sources are adequate. Further development of other line-clearing tools will make a great improvement in line production over the axe, pulaski, or brush hook. Line-scraping tools such as the shovel, pulaski, McLeod are too slow. Two machines have been developed, one a flail-type and the other a rotary-disc-type. Further work by the Arcadia Equipment Laboratory on these two machines should soon provide improved models that will fill an important need. Other equipment for burning out and line holding may be developed after line-clearing and line-scraping needs are adequately met.

Lacking such devices as those mentioned above on a practical scale, we need to make better use of what we have now.

1. Helicopters now available to us are a valuable tool. In 1953, during a period when all smokejumpers were in use and we had additional back-country fires needing attention, we assigned a helicopter to one ranger district to use for initial-attack transportation. This district is probably our only wilderness-area district that has a fairly adequate number of helispots. On three of the fires on which the helicopter was used for initial attack and reinforcements, it was estimated that savings in suppression costs over ground travel amounted to $89,500. The helicopter was also invaluable during this period on conventional uses such as scouting and ferrying overhead and skilled fire fighters between project fires.

   With helicopters of large pay load now being produced, we need to plan where we can economically use them when this service becomes available to us.

2. Motorcycle or scooter travel on trails would speed up ground travel in a limited way - provided trails could be improved to a sufficiently high standard. In Region 1 we are making slow progress on such a program in roadless areas outside the designated wilderness areas. In the latter areas in Region 1 it would not be desirable, even if present regulations were revised, because of unfavorable public reaction. I do not believe the gains in fire control would be worth the loss to wilderness-area recreation interests. If the Forest Service were to use

mechanical ground-travel methods in designated wilderness areas, it would indeed be difficult to prevent others from doing likewise. However this kind of travel may be needed and acceptable into some limited areas and its use should be considered.

3. We also need to currently review our fire plans and accomplishments, revise where needed, and make sure we do a good job in the fundamentals of prevention, detection, preparedness and suppression with the means available to us.

SUMMARY

In the relation of fire management to other resource management work in inaccessible areas, we need to consider area by area, the constituents of resource management and their priorities. The principal values of water, game, recreation, or other, may vary greatly between areas. In Region 1, our primary objective in designated wilderness areas is water management. In the Columbia drainage, water management calls for practices to better distribute the flow - take some off the peak flow and add some to the low-flow period. In the Missouri drainage, holding the soil in place and making more water available appears to be the best present management objective. We know considerable about how fire affects attainment of these objectives - we need to know more - and by integration with engineering works can plan fire control needs in accordance therewith. We aim primarily at maximum retention of soil with room for limited manipulation for recreation and wildlife. This calls for good fire protection. We believe this is a sound policy for Region 1 wilderness areas.

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SUPERVISION
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MAJOR TOPIC II - RELATION OF FIRE MANAGEMENT TO OTHER RESOURCE MANAGEMENT WORK.

Subtopic B- Standards of Fire Protection by Management Units

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STANDARDS OF FIRE PROTECTION BY MANAGEMENT UNITS

The development of this topic calls for treatment of the following two major questions:

1. Should forest fire protection standards be established for each management unit or continue to be based on broad areas such as a forest region?
2. What standard of fire protection is required to permit effective resource management, and how shall this standard be determined?

In answering these questions my discussion and the conclusions reached will be largely confined to the timber resource. However, the methods for determination of fire protection standards will apply equally well to other resource values. In the final analysis, under the principle of multiple use management, fire protection standards must be based on prevention of damage to the entire resource, rather than to a part of it such as timber.

First, I will discuss and recommend the units for which fire protection standards should be established. Fire protection standards to date have, to a large extent, been very general and have been applied on a broad scale. Since my entry into the Forest Service in 1934, and prior to that time, fire control objectives have been expressed and success of protection measured in terms of allowable annual burn per million acres protected. The acceptable percentage in burned area is variable ranging from .1 of one percent to about 1 percent depending upon the kind of forest cover protected. The burned area used in computing the percent burned includes all kinds of cover and all degrees of burn. Besides, the area to which the percentage is applied usually involves a national forest or even a

region. Seldom is it applied to a resource management unit such as a working circle, grazing allotment, recreational unit or a watershed. Thus on a particular working circle, fire occurrence and damage may far exceed the allowable burn objective but for the forest as a whole the objective may be met. This situation if allowed to continue could result in removing from production a good portion of a management unit with the resultant effect of depriving the industry or industries of raw material and the people of a source of income for which they are dependent. What is the answer to such a situation? To me the answer is clear. We must take a new look at our fire protection standards and direct our fire control efforts in such a way that each management unit will be provided with the degree of protection necessary to permit effective resource management on a sustained yield basis. We must think, talk, plan, execute and measure fire protection on a management unit basis rather than in terms of percent of allowable burn for broad areas. The determination of allowable annual burn for each management unit should be placed at the same level of importance as the determination of allowable annual cut or allowable annual use.

The establishment and size of management units for which standards of protection should be established will depend upon the purpose of management. If the primary purpose is timber production the management unit will generally be the working circle which is defined in SAF "Forest Terminology" as "a forest area from which a sustained yield of forest products is planned." The size of working circles depends upon many factors but the three main factors are:

1. An area with sufficient productive capacity for practicable sustained yield.
2. An area with present or potential transportation facilities which permit the flow of products to dependent industries. Topography is important in this regard.
3. An area which will provide employment opportunities and stability to dependent communities. In some instances communities will be entirely dependent upon forest products.

There are other factors which are considered such as administration, type of timber, natural flow of forest products, etc., which affect the size of the working circle. The range in area is generally between 100,000 and 400,000 acres.

If it is agreed that standards of fire protection should be established for management units, the question then arises how shall these standards be determined? My discussion of this problem and the resultant conclusions involves two basic principles of fire protection:

1. That the only real purpose of fire protection is the prevention of damage to the resource being protected;
2. That the intensity of protection depends upon how much loss the resource manager is willing to accept.

If the cost of protection is considered a debit against the resource along with the damage to the resource, then the intensity of protection that will result in the minimum cost and damage is the standard of protection desired. However, if the resource manager is able to establish a damage figure in percent of the total resource above which management

cannot be effective, then the standard of protection can be based primarily on anticipated damage. I have approached the problem from two angles and confined my discussion almost entirely to timber in order to more clearly present the methods recommended for determination of protection standards. The first method to be discussed will be "Minimum Cost and Damage" as applied to a specific unit of management.

Before a discussion of the above two methods for determining allowable annual burn, it seems desirable to explain what is meant when the term "Base" allowable annual burn is used. This base allowable annual burn assumes 100% destruction of resource values computed as of rotation age. This is the base against which fire protection accomplishments will be measured. It will be subject to change periodically as costs and values change. A common base such as this is needed to measure the effectiveness of fire protection as the amount of damage caused by individual fires may vary greatly.

Factors to Consider in Establishing Standards of Protection

The principle factors to consider in the establishment of standards of protection under the minimum cost and damage method are:

1. Fire damage
2. Objective of Management
3. Rotation
4. Delay in regeneration as result of fire
5. Protection costs
6. Cost of regeneration by artificial means
7. Potential benefits to society without fire

8. Allowable burn in percent

These factors will be discussed separately to show the influence they have on the establishment of standards of protection.

Fire Damage

There are many kinds and degrees of damage resulting from fire. These damages can be classified according to one's ability to evaluate them. In this regard, two classes of damage are recognized; namely, tangible and intangible.

Tangible damage results in losses which can be evaluated quite accurately in monetary terms as those losses involve tangible things which have a going market value. Intangible damage, however, results in losses which are very difficult to evaluate in monetary terms as it does not have a generally recognized market value.

Determination of monetary loss as a result of intangible damage must be based to a large extent on judgment after assembling and analyzing all the facts available. Consequently, intangible values are less exact and much more difficult to defend than tangible values. However, the fact that intangible values are difficult to determine should not prevent their determination and use in establishing fire protection standards. The fact that they are difficult to determine should offer a challenge to resource managers to conduct research and develop appraisal methods based on scientific facts which will more accurately reflect these monetary losses.

As the only justification for a fire control organization is to prevent damage, the evaluation of potential damage and the cost of preventing this damage is vital in the establishment of standards for fire

protection. In order that we may have a better understanding of the kinds of damage that result from fire, I am listing these most commonly thought of under two classifications.

Tangible Damages

1. Commercial forest products
2. Improvements
3. Forage
4. Young timber growth
5. Fire suppression costs
6. Cost of rehabilitation

Intangible Damages

1. Watershed values
2. Wildlife and wildlife habitat damage
3. Fish and fish habitat damage
4. Loss in scenic recreational values
5. Site deterioration
6. Interference with natural processes of regeneration of timber and forage species
7. Effects on stability of income and standards of living for a given area.
8. Effects on future fire protection costs.

The above list is by no means complete but it will serve as an example of the kinds of damage which occur and which must be evaluated in establishing a sound economic fire control system.

There are all degrees of damage ranging from 100% to practically no damage. Consequently the amount of damage must be determined to measure the effectiveness of fire protection. In the determination of percent of allowable annual burn, I have first established a base figure based on 100% damage at rotation age. I think this approach is needed in establishing standards of protection. The base figure then serves as a goal or objective upon which the effectiveness of fire protection can be measured. To illustrate, let's assume an allowable annual burn of 200 acres for a management unit of 100,000 acres. This is the base figure. Five fires occurred during the year and damage was measured as follows:

1.	200-acre fire in longleaf pine	10% damage =	20 acres
2.	100-acre fire in shortleaf pine	30% damage =	30 acres
3.	40-acre fire in hardwoods	50% damage =	20 acres
4.	50-acre fire in pine sawtimber	100% damage =	50 acres
5.	300-acre fire in pine sawtimber	20% damage =	60 acres
Total	690 acres		180 acres

Under the present method of measuring effectiveness of fire protection a burn of 690 acres would far exceed the allowable annual burn, but in reality when damage is taken into account, the goal of 200 acres was attained.

Objective of Management

The objective of management is an important factor to be considered in the establishment of standards of protection as it definitely influences the resource manager in the determination of fire damage. Public agencies

such as the Forest Service must consider multiple-use management for the benefit of society; whereas, private ownership may emphasize a single use such as timber production. Consequently, a private owner may disregard damage to wildlife, fish, forage, recreation and watershed values and base his protection on timber values only. The kind of products to be produced may also affect standards of protection when expressed in percent of allowable annual burn and with the understanding that this base figure means total damage. On this premise, an owner, managing his property for the production of pulpwood on a short rotation, can withstand a higher percent of allowable annual burn than an owner managing his property for sawlog production on a longer rotation. For example, let us assume two management units of 100,000 acres each, one to be managed for pulpwood on a 40-year rotation and the other to be managed for sawlogs on a 100-year rotation. In order for the pulpwood unit to be on a comparable basis with the sawlog unit, the allowable annual burn of the pulpwood unit could be 2-1/2 times larger than the lawlog unit, if only area burned during the rotation is considered and other factors are equal.

Rotation

Rotation age is another factor which must be considered in establishing percent of allowable annual burn. As pointed out under objective of management, an increase in rotation age has the effect of reducing percent of allowable annual burn that can be tolerated, assuming, of course, that all other factors remain constant.

Delay in Regeneration as a Result of Fire

A delay in regeneration simply means a longer period necessary to grow a crop of timber. If the average rotation age is 100 years but as a result of fire it takes 20 years to establish a stand, then the time between final harvests becomes 120 years instead of 100. This increase in time between final harvest reduces the percent of allowable annual burn that can be tolerated and further emphasizes the fact that an average percent of allowable burn for a broad area cannot be used with safety for each management unit.

Protection Costs

Protection costs vary in direct proportion to the intensity of protection. As protection costs are increased, theoretically, damages should decrease. The objective of fire control should be to determine the point where the last dollar of fire control costs expended is offset by a dollar of damage prevented. It will probably never be possible to prevent all damage as the cost would be prohibitive. However, we can strive for the point of equilibrium which will return as benefits to society the maximum net value from the management unit. We should not be content to spend a dollar for protection and expect to receive as benefits only $.50 in damage saved. Money spent for protection without a corresponding monetary reduction in damages is a direct financial loss and is contrary to the principle of minimum cost and damage.

Cost of Regeneration by Artificial Means

Cost of regeneration following fire must be considered a damage as it reduces the potential monetary return from the management unit. This is

one form of damage that generally is fairly easy to evaluate as it involves something tangible such as cost of planting or seeding. It should be understood in establishing standards of protection by application of the minimum cost plus damage method that each timbered acre damaged by fire should be returned to full timber production by natural or artificial means regardless of cost. This policy, of course, assumes that timber production is the highest use of the land. If this policy is not followed, there could be a gradual reduction in area of timber-producing land which might result in removing large areas from timber production. Cost of regeneration which is a form of damage has not been fully evaluated in all cases, especially in the dry ponderosa pine sites in the west. Cost of regeneration on such sites may in some instances exceed the value of the final crop. In such cases protection from fire is highly important as losses may be extremely high. Fire damage from a timber management standpoint must not only include the loss to the existing stand but also the cost of establishing a new stand to keep the area in timber production.

Potential Benefits to Society Without Fire

The potential benefits to society without fire should include in monetary terms all values tangible and intangible which society will receive from the area during the rotation period. The determination of these values or benefits to the best of one's ability is essential in establishing standards of protection. It is obvious that one must know the values to be protected in order to determine how much can logically be expended

to protect them. If annual returns without fire are only $1.00 per acre, the amount that should be expended for protection is naturally less than if the returns were $10.00 per acre.

It should be fairly easy to compute timber values for the management unit during the rotation period. Timber value can be determined by multiplying the expected yield by the estimated average stumpage value. Determination of other values such as watershed, recreation and wildlife is much more difficult. I do not intend to indicate how these values can be determined. This is a subject that requires special treatment, and definite instructions and procedures are needed to appraise these values. This is a fertile field for free thinking individuals, and, if their combined efforts result in a practical method or methods of appraising these values, this will certainly be a big step forward in fire control planning.

Calculation of Allowable Annual Burn

a. Minimum cost and damage method

In the application of the minimum cost and damage method, the problem is to determine the highest monetary return to society after taking into account cost of protection and damage. The object is to reduce damage to the lowest possible figure without reducing the highest monetary returns.

The following sample computations will serve to illustrate how allowable annual burn may be calculated. I have used timber values in the computation, but other resource values and damage can and should be included in the final determination of allowable annual burn.

Let:

R = Rotation period in years

P = Percent of damage

a = Allowable annual burned area in percent

X = Annual protection costs per acre

Y = Potential benefits to society in dollars without fire per acre during rotation

A = Area of management unit in acres

Z = Regeneration period in years

C = Total cost of regeneration during rotation resulting from fire

Then: $AY - \sqrt{(R + Z)\ (P)\ (a)\ (AY) + XA\ (R + Z) + C} =$ Net return

When: AY = Potential return to society from management unit without fire during rotation.

(R + Z) (P) (a) (AY) = Estimated fire loss during rotation

XA (R + Z) = Cost of protection during rotation

C = Cost of regeneration during rotation

Assume: R = 90 years

P = 100% (always base calculations on 100% destruction by fire)

a = 0.2%

X = $0.20 per acre

Y = $500 per acre

A = 100,000 acres

Z = 10 years

C = $400,000

Solving: AY = 100,000 x $500 = $50,000,000

$\left[(R \div Z)\ (P)\ (a)\ (AY) \right] = (90 \div 10) \times 100\% \times .002 \times 50{,}000{,}000$

$= \$10{,}000{,}000$

XA $(R \div Z) = \$.20 \times 100{,}000 \times (90 \div 10)$

$= \$2{,}000{,}000$

$= \$400{,}000$

Then: Net return $= \$50{,}000{,}000 - (10{,}000{,}000 + 2{,}000{,}000 + 400{,}000)$

$= \$37{,}600{,}000$

Let us assume that all factors are constant except that allowable annual burn is reduced to 0.1% and by so doing the annual cost of protection will increase to $.70 per acre and the cost of regeneration will decrease to $200,000. Then by use of the formula this result is obtained:

Net return = $50,000,000 - ($5,000,000 + 7,000,000 + 200,000) = $37,800,000

By increasing the cost of protection and reducing the damage in half plus the saving in cost of regeneration, a .1% allowable annual burn is just about the same in net return as an allowable annual burn of .2% but by better protection just twice as much raw material is available to society.

Now let us further reduce the allowable annual burn to .05% and see what will happen. This will increase the protection costs to $2.00 per acre but will reduce cost of regeneration to $100,000.

Then net return = $50,000,000 - (2,500,000 + 20,000,000 + 100,000)

= $27,400,000 return to society

This is obviously less favorable to society than the .1% allowable annual burn for by investing an additional $13,000,000 in protection costs damage was reduced only $2,600,000.

b. Maximum permissible damage method

This method of determining allowable annual burn is different than the minimum cost and damage method in that it establishes the maximum damage that can be sustained in the opinion of the resource manager without direct reference to the cost of protection. However, the resource manager, in the determination of the maximum damage that can be sustained and permit

effective management, must give some consideration to the cost of protection. It would be out of the question to establish a maximum percent which would cost a prohibitive amount to attain. Consequently, considerable judgment must be used in setting this maximum percent.

At a fire conference held in Washington, D. C. in the spring of 1930, it was determined that a .1% allowable annual burn in the timber types (white pine and spruce) could be tolerated. Fire in these types cause almost 100% destruction so that .1% allowable annual burn as a base can be considered an expression of total damage to the timber resource. This percent of allowable annual burn amounts to a 10% loss in timber values during a rotation period of 100 years, assuming, of course, every acre burned was mature and ready for harvest. This is not the case for in a normal forest all age classes are represented and each age class has an equal chance of being burned if risk is disregarded. Therefore, to take into account age classes, just one-half of 10% or 5% should be used as the maximum loss that could be tolerated. This percentage of loss could well be varied by timber types, depending upon their value, for the more valuable a property is the more need for protection to reduce loss.

After the percent of loss or damage is established for each timber or cover type, the percent of allowable annual burn can easily be determined by dividing the percent of loss or damage during the rotation by the rotation period in years. For example:

$$\frac{5\% \text{ permissible damage during rotation}}{100 \text{ years rotation period}}$$

= .05% allowable annual burn

This approach as in the minimum cost and damage method assumes complete destruction of timber values and that every acre of commercial forest land burned will be returned to timber production as soon as possible either by natural or artificial means. This method, however, does not take into account the cost of regeneration and cost of protection as does the minimum cost and damage method.

Application of the Calculated Allowable Annual Burn Percent to a Management Unit

In applying the calculated allowable annual burn percent to a management unit, the following three assumptions should be made:

1. The allowable annual burn as calculated is a base figure and is an expression of total loss in resource value at rotation age.
2. This base figure must be calculated for each timber type in the management unit.
3. Every acre of commercial forest land will be returned to production as soon as possible either by natural or artificial means regardless of cost.

With these assumptions in mind and the base figures in terms of allowable annual burn determined, the area of permissible allowable annual burn for any given management unit can be calculated. To illustrate, I will show the results in table form for a sample management unit of 100,000 acres.

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BASIC DATA FOR MANAGEMENT UNIT

Timber Type	Area in Acres by Size Class					Rotation (Years)	% Allowable Annual Burn	Base Allowable Annual Burn (Acres)	Acre Equivalent to Average Base
	Seedling and Saplings	Poles	Small Sawtimber	Large Sawtimber	Total Area				
White Pine	5,000	5,000	5,000	5,000	20,000	120	.05	10	4.6
Spruce	2,000	3,000	3,000	2,000	10,000	120	.05	5	4.6
Hemlock	2,000	3,000	3,000	2,000	10,000	120	.2	20	1.15
Larch-fir	5,000	5,000	5,000	5,000	20,000	120	.1	20	2.3
Lodgepole	5,000	5,000	5,000	5,000	20,000	100	.2	40	1.15
True firs	3,000	3,000	2,000	2,000	10,000	100	.25	25	.92
Non-commercial	---	---	---	---	10,000	---	1.0	100	.23
TOTAL	22,000	24,000	23,000	21,000	100,000	---	.23	230	1.00

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The table indicates the base calculated allowable annual burn for the management unit and for each timber type based on its area. It also indicates the acre equivalent by types to the average for the unit. For example, 10 acres of white pine burn is equivalent to 46 acres when compared to the average for the unit.

The calculation presented in the table is as far as one needs to go in establishing standards of protection for management unit. However, in measuring accomplishments of fire protection in relation to the established standards, it is necessary to measure the damage resulting from each fire in relation to total damage as expressed in the base allowable annual burn. There are two factors involved in this computation:

1. The average age of the stand burned
2. The percent of damaged caused

For example, let's select a hypothetical fire record for the management unit for one year and go through the computation and show the results in table form.

Fire Record

20 acres of white pine poles 100% damage

30 acres of lodgepole pine saplings 100% damage

100 acres larch-fir large sawtimber 30% damage

100 acres non-commercial forest land 40% damage

In converting the above fire record to a common base that will reflect extent of total damage and measure the effectiveness of fire control in relation to established standards, the following formula may be used:

$\frac{a}{R} \times P \times A \times E =$ Area equivalent.

When: a = Age of stand

P = Percent damaged

R = Rotation

A = Area burned

E = Acre equivalent

FIRE RECORD SHOWING EFFECTIVENESS OF CONTROL

Base Allowable Annual Burn - 230 years

Timber Type & Condition Class	Area Burned (acres)	% Damaged	Average Age	Rotation	Acre Equivalent	Area Equivalent (acres)
White pine poles	20	100	40	120	4.6	30.7
Lodgepole pine saplings	40	100	15	100	1.15	6.9
Larch-fir large sawtimber	100	30	110	120	2.3	63.5
Larch-fir poles	100	70	50	120	2.3	67.0
Non-commercial	100	40	--	--	.23	9.2
	360					177.3

The above analysis of an annual fire record indicates the effectiveness of fire protection in relation to the standards established. This record should be maintained in somewhat the same manner as cutting records for in each an allowable annual figure for the management unit is established. In this particular example even though the base allowable annual burn in acres for the management unit (230 acres) has been exceeded on the basis of area burned, the area equivalent based on damage is below the standard indicating satisfactory protection.

From the above discussion, I have tried to point out the desirability of critically examining present standards of fire protection, management unit by management unit, and to the best of our ability establish standards which will return in monetary terms the largest benefits to society. If either of the methods I have discussed are used, each management unit will probably have a different standard of protection for to be similar with others all factors relating to potential benefits, potential damage and cost of protection would also have to be similar. It is very likely that a shift in the intensity of protection will result. Some areas may be in need of more intensive protection and others may at present be over-protected. It will be up to resource managers and fire control planners to establish standards of fire protection which will stand the test of economic analysis. This will require a much better understanding and appraisal of values to be protected and damage caused by fire. To place fire protection on a sound economic basis is a big and very important job and one that should return much satisfaction to the planners and substantial savings to the general public.